EMPIRICAL STUDIES ON CHANGES IN OIL GOVERNANCE

by

Mohammad Kemal

A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Mineral and Energy Economics).

Golden, Colorado

Date______________________________

Signed: ______________________________

Mohammad Kemal

Signed: ______________________________

Dr. Ian Lange
Thesis Advisor

Golden, Colorado

Date______________________________

Signed: ______________________________

Dr. Michael R. Walls
Professor and Division Director
Division of Economic and Business

ABSTRACT

Regulation of the oil and gas sector is consequential to the economies of oil-producing countries. In the literature, there are two types of regulation: indirect regulation through taxes and tariffs or direct regulation through the creation of a National Oil Company (NOC). In the 1970s, many oil-producing countries nationalized their oil and gas sectors by creating and giving ownership rights of oil and gas resources to NOCs. In light of the success of Norway in regulating its oil and gas resources, over the past two decades several countries have changed their oil governance by changing the rights given to NOC from ownership right to mere access rights like other oil companies. However, empirical literature on these changes in oil governance is quite thin. Thus, this dissertation will explore three research questions to investigate empirically these changes in oil governance. First, I investigate empirically the impact of the changes in oil governance on aggregate domestic income. By employing a difference-in-difference method, I will show that a country which changed its oil governance increases its GDP per-capita by 10%. However, the impact is different for different types of political institution. Second, by observing the changes in oil governance in Indonesia, I explore the impact of the changes on learning-by-doing and learning spillover effect in offshore exploration drilling. By employing an econometric model which includes interaction terms between various experience variables and changes in an oil governance dummy, I will show that the change in oil governance in Indonesia enhances learning-by-doing by the rigs and learning spillover in a basin. Lastly, the impact of the changes in oil governance on expropriation risk and extraction path will be explored. By employing a difference-in-difference method, this essay will show that the changes in oil governance reduce expropriation and the impact of it is different for different sizes of resource stock.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENT

Al-hamdu lillahi rabbil ’alamin, for only with His will and blessings could I have had an invaluable opportunity to learn abroad in a prestigious school and also have enough strength to complete all the requirements for a Ph.D. degree.

The completion of this dissertation and all the rigorous process that preceded is (16 classes, 2 Ph.D. qualifying exams, 5 brownbag/graduate seminars, 2 conference seminars, proposal defense and thesis defense) can only be done with kindness, sweat, tears and unconditional love from my wife, Rosmala Rais, who provided support and love for me and my three beautiful girls, Ayasha, Alisha and Azzura.

Just like other great things in my life, this whole process of finishing my Ph.D. degree can only be possible with doa, love and support from my mother and mother in-law, my four beautiful sisters and my siblings in-law. They are truly my life supports.

I am indebted to Professor Ian Lange for his guidance in shaping my research. I am also thankful to Professors Elizabeth Davis, Harrison Fell and Peter Maniloff for their invaluable directions and comments.

To live far away from family is hard and therefore, I am grateful to all my friends and their families in Colorado who provided me and my family with family-like love and support (the Akimayas, Badruddins, Irfanos, Nurhasans, Noorcahyos, Prasetyos, Rahmans, Sadagoris, Sugiantos, mbak Fifi and family, mbak Penty and family). All of you are forever in our hearts.

Lastly I am also thankful to people in my office, particularly the former chairman, Office of the Chairman teams and Human Resources teams who provided me with opportunity and scholarships to pursue this Ph.D. degree.

To my late Bapak who put education above all else

CHAPTER 1

INTRODUCTION

During the 1970s, many oil-producing countries gave National Oil Companies (NOC's) ownership rights to oil and gas resources. Following the success of Norway in managing its oil and gas resources, development institutions have tried to push oil-producing countries to change their oil governance. Over the past two decades, several countries have done so by enacting laws that create a regulatory entity and establish the NOC only as a business entity. Thus, these NOCs now are only given access rights to explore and produce oil and gas like other international oil companies. This dissertation explores empirically the impact of these changes in oil governance. It consists of three essays which study the impact of these changes on aggregate domestic income, on learning-by-doing and learning spillover effect and on expropriation risks and extraction path. These three essays will be summarized in this chapter.

Chapter 2 aims to empirically investigate the impact of changes in oil governance, specifically of changes in allocation of ownership rights versus access rights, to aggregate domestic income. Using data from 35 countries in the period 1990-2012 and employing a difference-in-difference method, my results suggest that a country which creates a separate regulatory entity and makes the NOC merely a business entity increases its aggregate domestic income by around 10%. I further explore the impact on different political institutions and find that the impact of the changes to aggregate domestic income is higher in non-democratic (autocratic and anocratic) institutions than in democratic institutions. I also find the impact is higher on countries whose contributions to their GDP from the oil and gas sector are high. This empirical evidence has an important policy implication and can be used as guidance for governments of oil-producing countries that are seeking the best way to govern their oil and gas sectors.

Chapter 3 investigates the impact of changes in institutional design of oil governance on the learning-by-doing and learning spillover in the oil and gas industry in the South East Asia region. Learning-by-doing is an important field in the economics literature and is supported by many empirical evidences from various industries including oil and gas. However, none of the studies in the oil and gas industry find learning spillover, which has been found in other industries and is consequential in sustaining an increase in efficiency. By observing a new dataset on offshore exploration drilling efficiency in the South East Asia region and employing an econometric model which contains an interaction term between an institutional design dummy and learning variables, this essay finds that a change in the institutional design of oil governance in Indonesia enhances learning-by-doing specific to the rig and learning spillover across oil companies within a basin. This result is important particularly to oil-producing countries that want to sustain their oil production because to sustain oil production, exploration drilling which level will depend on the unit cost is vital. Therefore, changes in the institutional design of oil governance which can influence learning-by-doing and learning spillover are important parts of sustaining oil production.

In Chapter 4, I observe the impact of a change in institutional design of oil governance in Indonesia on expropriation risk and extraction path. The impact of expropriation risk on the extraction path of non-renewable resources has been shown to be theoretically ambiguous. It depends on capital intensity of the extraction process and the size of resource stocks. Since the impact is theoretically ambiguous, a solution is available from the empirical results. I make an inference that a change in oil governance reduces expropriation risk, and the impact of the reduction in expropriation risk on the extraction path is different for different sizes of resource stock. These results confirm the theory that for small resource stocks, reduction in expropriation risk leads to a slower extraction path. This reiterates the importance of strengthening ownership rights such that expropriation risk can be reduced, over-extraction can be avoided and more sustainable economic welfare can be achieved.

CHAPTER 2

OWNERSHIP RIGHTS VERSUS ACCESS RIGHTS ALLOCATION TO CRITICAL RESOURCES: AN EMPIRICAL STUDY OF THE ECONOMIC IMPACT OF CHANGES IN OIL GOVERNANCE

Oil and gas sector is important to country’s economy and therefore how the government regulate it is consequential. Over the past two decades, several countries changed their oil governance by enacting laws that create a regulatory entity and establish the National Oil Company (NOC) only as a business entity. Thus, these NOCs now are only given access rights to explore and produce oil and gas like other international oil companies. This chapter aims to empirically investigate the impact of changes in oil governance, specifically of changes in allocation of ownership rights versus access rights, to aggregate domestic income.

2.1 Introduction

In oil-producing countries, oil and gas play an important role in shaping their economy. Grayson (1981, p.1) termed the oil and gas sector “the commanding height of economy”. According to World Bank data in the period of my observation (1990-2012), rents from oil and gas can contribute up to 70% of a country’s GDP. Therefore, regulation of oil and gas resources by the government of oil producing countries will have a significant impact to the economy. Government can regulate the sector indirectly through tariffs, taxes and licenses or directly through the creation of a National Oil Company (NOC). This paper is interested in the latter, particularly in the regulation of rights (ownership rights or access rights[1]) given to NOCs. Historically, many oil-producing countries gave ownership rights to their NOC. Thus, the NOC not only had access rights to explore and produce in a working area but also to hold bidding rounds, to award, regulate and monitor contracts and to collect revenue from other oil companies. However, recently, some oil-producing countries have enacted laws that create a separate regulatory entity and establish the NOC purely as a business entity that only has access rights to explore and produce like other oil companies.

To my knowledge, there has been no empirical study of the impact of these changes in oil governance (i.e., changes from giving a NOC ownership rights to just access rights) on aggregate domestic income. Therefore, this paper aims to answer the research question: What is the economic impact of changes in oil governance? To put my research question in broader economic terms, this paper aims to answer empirically whether the state's withholding ownership rights and granting access rights to all agents is superior to granting ownership rights to one agent (the NOC).

The question is answered by employing a difference-in-difference methodology with aggregate domestic income of the country as the dependent variable. The result shows that countries that change their oil governance increase their GDP per capita by around 10%. This result is statistically significant and robust to changes of control variables and number of countries. I further explore the impact on different political institution, and find that the impact of the changes to aggregate domestic income is higher in non-democratic (autocratic and

---

[1] This paper uses the definition of ownership rights and access rights in the incomplete contract literature which ownership right is defined as the residual right of control or the right to use the asset that is not contractible and access right is defined as the ability to work with critical resources without getting residual rights of control.

anocratic) institutions than in democratic institutions. I also find the impact is higher on countries whose contributions from oil and gas sector to their GDP are high.

This analysis can guide governments of oil-producing countries that are seeking the best way to govern their oil and gas sectors. Thurber et al. (2011) build case studies on several important oil-producing countries and make qualitative inferences about the impact of just giving access rights to the NOC on sectoral oil performance, but they did not provide an empirical model to test it. Thus, this study will provide empirical evidence on the impact of changes in oil governance, which is important particularly for those countries who are considering whether to change their oil governance.

In addition, Rajan and Zingales (1998) have shown theoretically that withholding ownership and granting access rights to all agents is a superior mechanism to granting ownership to one agent and access rights to all other agents, but they did not provide empirical evidence to support their theory. Thus, this paper will be the first study which provides evidence to support this theory in the oil and gas industry setting.

In order to answer the research question, the remainder of the essay will proceed as follows. First, I will provide a conceptual framework for how changes in oil governance could impact the aggregate domestic income. Second, I will explain my econometric model and methods. I will also provide the results and concluding remarks.

2.2 Conceptual Framework

In this section, I will provide a brief explanation of the changes in oil governance and some transmission mechanisms based on related previous literature on how these changes impact aggregate domestic income.

In order to explore and produce oil and gas, the state as de jure owner of the oil and gas resource needs to work with technological provider's agents. These agents are oil and gas companies who have the capital and technology to explore and to produce oil and gas. Typically, in order to work with an agent, the state entity or its NOC who has the ownership right of oil and gas resources will split the area which contains oil and gas resources into several working areas or blocks. The holder of the ownership rights will then hold a bidding round to tender these working areas. After awarding the contract, the holder of the ownership rights will monitor and regulate the contract and collect revenue from it.

With regard to the rights given to a NOC, the resource nationalization literature (Guriev, Kolotilin, and Sonin, 2011; Mahdavi, 2014b; Stevens, 2008) shows that during the 1970s, many oil-producing countries nationalized their oil and gas resources by creating NOCs as the dominant agent in their oil and gas resources extraction. As the dominant agent, these NOCs would hold bidding rounds, award, regulate and monitor contracts as well as collect revenue from other oil companies. Thus, they function not merely as a business entity like other oil companies (international or domestic) who have just been given access rights to explore and produce in a working area but also as a policy and regulatory entity. Hence, these NOCs are given ownership rights to oil and gas resources.

By contrast, Norway, which has been considered successful in developing its oil and gas resources, has had a clear separation between policy, regulatory, and business functions since oil and gas extraction began there in 1972. The policy-making function is carried out by the Ministry of Petroleum and Energy and the regulatory function is carried out by the National Petroleum Directorate (NPD). Statoil, which is the NOC, only functions as a business entity like other oil companies and thus only has access rights to explore and produce. In a recent work, Mideksa (2013) employed a synthetic control method to investigate the impact of oil and gas extraction in Norway and found that oil and gas extraction increased annual GDP by 20%. Therefore, as argued by Thurber et al. (2011), the Norwegian model of oil governance in which the NOC functions only as a business entity has been promoted by development institutions to be adopted by other oil-producing countries.

During the 1990s and 2000s, several countries have changed their oil governance by enacting laws that create regulatory entities and establish the NOC as a business entity that only has access rights. These countries are Peru, India, Brazil, Indonesia, Colombia, Algeria, Ecuador, and Turkmenistan. Based on the literature which will be described below, I hypothesize that the changes in oil governance will increase sectoral profitability due to an increase in investment incentive and sectoral efficiency and thus have a positive impact on aggregate domestic income.

The first stream of literature that supports the hypothesis is the incomplete contract literature. Rajan and Zingales (1998) argue that in an incomplete contract[2], regulation of rights to critical resources is an important factor. They argue that access rights are better than ownership rights because with access rights, the agent is more motivated to make the efficient level of investment. Rajan and Zingales also show that allocating ownership to a single agent and access rights to other agents results in lower total specific investment than withholding ownership and granting access to all agents and that by withholding ownership and granting access to all agents, the state will increase the incentive for all agents to invest. This is so because by conveying the ownership right which gives the right to award the contract, the NOC would be strategizing over

---

[2] Contracts between states and oil companies are typically long-term (20-30 years). Moreover, these contracts start with the exploration phase; negotiation on more detailed agreement will start after discovery of recoverable reserve. Thus, it is an incomplete contract.

which working areas should be awarded to other oil companies. Awarding a more lucrative oil and gas working area to another oil company would reduce the NOC’s incentive to invest. Likewise, awarding a less lucrative oil and gas working area to other oil companies would reduce other oil companies’ incentive to invest.

Another stream of literature that supports the hypothesis is the study of the impact of ownership rights in terms of risk of expropriation using a dynamic model of oil extraction. Bohn and Deacon (2000) develop a theory and also find empirically that risk of expropriation can discourage private investment. They show that optimal ratio of capital to reserve is an increasing function of price and decreasing function of expropriation risk. Guriev et al. (2011) argue that expropriation risk increases in periods of high oil prices, when there are few checks and balances on the government, and when there is an increase in the managerial and technical capabilities of oil-producing countries since these will increase the government’s outside options. Hence, oil governance in which oil companies are making contracts with the NOC has a higher expropriation risk because the NOC has technological and capital capability to expropriate whenever the outside option value is high. This condition is different when the contracting party is a state entity who does not have the technological and capital capability to take over the operation after the expropriation. The state entity can appoint the NOC (or other oil company) to take over the operation but there will be a time gap to transfer knowledge and assets, which incurs an opportunity cost to the state. For that reason, changes in oil governance would reduce expropriation risk and hence, increase investment.

The literature on the efficiency of NOCs and International Oil Companies (IOCs) also supports the hypothesis. Hartley and Medlock (2008) and Eller et al. (2009) have shown theoretically (using a dynamic model of oil extraction) and empirically that due to their noncommercial objective, NOCs are less efficient. Therefore, oil governance which establishes the NOC merely as a business entity to explore and produce oil and gas will increase the efficiency of NOCs.

Lastly, in relation with learning by doing in the oil and gas industry literature which looks at the increase of efficiency (proxy by drilling rate) as experience of an agent increases (Kellog, 2011; Osmundsen, et al 2012), Thurber et al. (2011) argued that the regulatory entity has the ability to capture knowledge created by NOCs and other IOCs. Thus, a regulatory entity can create a positive knowledge spillover effect between oil companies operating in a country. This argument would require further research to empirically investigate the impact of changes in oil governance on learning by doing.

2.3 Econometric Model

The difficulty in empirical study of contract theory is to find a setting in which the contract is incomplete, specific investments are important (investments that have no value outside of the relationship) and ownership is changing (see Pérez-González (2004). I can overcome this difficulty by studying the impact of the changes in oil governance because the contracts between states and oil companies are incomplete[3] and the investments (e.g., exploration and development drilling, production facilities) have no value outside of the relationship and there are changes in ownership right given to NOC.

To empirically study the impact of changes in oil governance, this paper employs a difference-in-difference method. This is a popular method in estimating causal relationships and is widely used when one wants to analyze the impact of a policy change by analyzing data before

---

[3] See footnote 2.

and after the change is implemented. In this method, the impact of policy change is the difference in the difference of the outcome before and after the policy change for the treatment group relative to the control group. In this paper, the treatment group consists of countries which enacted a law that creates a separate regulatory entity and the control group consists of countries which have not enacted a law that creates a separate regulatory entity.

My analysis starts with 35 of the 49 countries listed as oil producers in the 2014 BP Statistical Review[4] who have a NOC as the dominant agent in their oil and gas extraction. These countries are significant oil and gas producer but the impact of the oil and gas sector on their economy might not be significant and thus I will not be able to see the impact of changes in oil governance to aggregate domestic income. Therefore, first I will drop countries whose percentage of contribution from oil and gas rent (source data World Bank) to GDP is less than 5%, which leaves 29 countries. A 5% threshold is arbitrary, but I will show later that the result is robust to changes in this threshold.

To identify my treatment group, first, I use secondary sources which discuss oil sector organization and NOCs (e.g., Victor, Hults and Thurber, 2012), the Energy Information Administration (2014) country analysis, and the World Bank's A Citizen's Guide to National Oil Companies (2008). I further confirm the policy through individual company or regulatory body websites and the law itself and find 8 countries which have enacted a law that creates a separate regulatory body. Table 2.1 in the next page shows the full list of the treatment group countries.

I analyze the impact of changes in oil governance on aggregate domestic income over the time span of 1990 to 2012. My difference-in-difference model is:

---

[4] To create a representative sample of oil producing countries, I choose countries listed in 2014 BP Statistical review which are accounted for 98.5% of world oil production.

$$= \quad + \quad + \quad + \quad + \qquad (2.1)$$

The dependent variables are log of GDP per capita, constant 2005 US$ (source: World Bank). My variable of interest is treatment dummy which is equal to 1 each year after a country enacted a law which creates a separate regulatory body and 0 otherwise (see Table 2.1). I also include other time-varying variables which have a significant relation to growth (Doppelhofer et al., 2004)) as my control variables. These control variables are oil production (source: BP statistical review), labor productivity (source: the Conference Board Total Economy Database), investment as a percentage of GDP and openness (source: PWT 7.1; Heston, Summers and Aten, 2012).

Table 2.1 Treatment group countries

No	Country	Law/Regulation	Year	Regulatory entity	Business Entity (NOC)
1	Peru	Hydrocarbons Law, Law N° 26221, 1993	1993	Perupetro	Petroperu
2	India	Resolution No. O-20013/2/92-ONG, D-III	1993	Directorate General of Hydrocarbon	ONGC
3	Brazil	Oil Law No. 9	1995	ANP	Petrobras
4	Indonesia	Oil and Gas Law No. 22/2001	2002	BPMIGAS	Pertamina
5	Colombia	Decree 1760	2003	ANH	Ecopetrol
6	Algeria	Hydrocarbons Law No. 05-07	2005	ARH and ALNAFT	Sonatrach
7	Turkmenistan	Law on Hydrocarbon Resources, 2008 (the agency was formed in 2007 by a presidential decree)	2007	State Agency on Management and Use of Hydrocarbon Resources	Turkmenneft
8	Ecuador	Correa Oil Law Reform	2010	Agencia de Regulación y Control Hidrocarburífero	Petruecuador EP

Moreover, as pointed out by Guriev et al. (2011) and Brunnschweiler and Valente (2013), expropriation risk which shapes investment incentives is correlated with checks and balances or the political regime of the government. This argument aligns with Thurber et al. (2011), who pointed out the importance of political competition and institutional quality to the success of changes in oil governance. Therefore, in an effort to control for political competition and institutional quality, I also include the Polity2 variable from the Polity IV data set (Marshall, Jaggers, and Gurr, 2010) which has been widely used in empirical studies as an explanatory variable for political competition and institutional quality (see Brunnschweiler and Valente, 2013; Cust and Harding, 2014; Guriev et al., 2011; Mahdavi, 2014a, 2014b). Polity2 is a composite variable derived from the democracy institution score (Democ variable) minus the autocracy institution score (Autoc variable). Democ and Autoc variables are scored from 0 to 10, with a higher number representing stronger democratic/autocratic institutions. Hence, the Polity2 variable ranges from -10 (strong autocratic institution) to +10 (strong democratic institution). All variables described above are in log scale except for the treatment dummy and polity variables[5].

2.4 Results

There are two key assumptions in the difference-in-difference method. First, as mentioned above, in the absence of treatment, the underlying difference between the treatment and control groups does not change and second, the treatment is exogenous. First assumption is tested by determining if the treatment and control group have the same trend in the pre-treatment

---

[5] I tried several specifications for the model, and Log-log specification gives the best fit and result of the model. Therefore, all variables are in log scale except for the treatment dummy and polity variables.

period. In order to check this assumption, I employ a model:

$$= \quad + \quad + \quad + \sum^{n} \quad + \sum \quad + \qquad (2.2)$$

With this model, I am able to capture the treatment effect in the pre-treatment period (parameter) and post-treatment period (parameter) so that I can see the trend of the treatment effect in the pre-treatment and post-treatment period. The result is showing (see Figure 2.1) that there are no significant differences prior to treatment and there is a significant break when treatment occurs. Thus, the first assumption is valid.

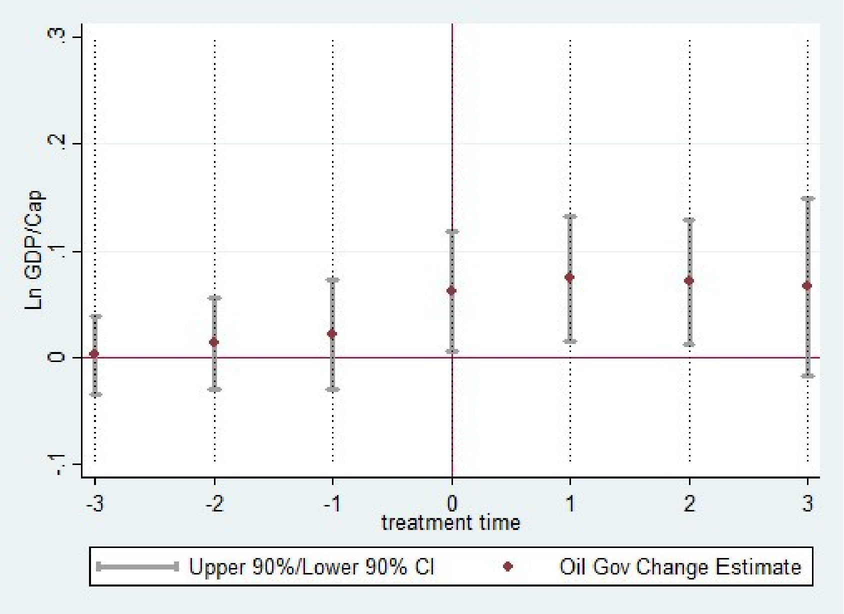

Figure 2.1 The impact of changes in oil governance on aggregate domestic income in the pre-treatment and post-treatment periods.

With regards to second assumption, one would be concerned that the oil price, which is one of the determinants of resource nationalization (Guriev, Kolotilin, and Sonin, 2011; Mahdavi, 2014b) is also correlated with changes in oil governance. Since the countries that change their oil governance are price takers (i.e. the changes in oil governance will not impact oil price), this concern can be tackled by controlling for oil prices through the time fixed effect. One would also concern if the decline in oil and gas productions might drive the changes. However, as shown in Figure A.1 in the Appendix, there are no significant differences in oil and gas production between treatment and control group before the treatment. Thus, oil and gas production should also not be a concern that can cause endogenous treatment effect. More importantly, the literature in changes in oil governance (see Thurber et al. (2011) and Stevens (2008)) stated that the changes in the role of the NOC are pushed by development institution and therefore exogenous to oil and gas industry problem.

Main estimation results using the difference-in-difference method are shown in Table 2.2 in the next page. Specification 1 is my simplest model and only includes a treatment dummy as an explanatory variable. The estimate of treatment effect from simplest model is not showing the expected sign. This result is biased because treatment dummy variable is correlated with labor productivity and polity variables which are also correlated with aggregate domestic income. After controlling for labor productivity and political institution, the estimate of treatment effect shows the expected sign and is statistically significant and robust.

The result suggests that changes in oil governance increase aggregate domestic income around 10%[6]. The results are statistically significant at the 90% level for specifications 3 and 4 and at the 95% level for specifications 5 and 6. The result is robust even after controlling for labor productivity, polity, oil production, investment and openness.

I further explore the impact of the changes in oil governance in different political institutions, specifically democratic, autocratic and anocratic institutions. In order to do that, I employ another model (equation 2.3) which includes an interaction term between the treatment

---

[6] This increase is not yearly but an average over treatment period.

dummy and the political institution dummy. In defining democratic, autocratic, and anocratic institutions, I follow the definitions used by Brunnschweiler and Valente (2013), who divide the polity variable ranging from -10 (strong autocratic institution) to +10 (strong democratic institution) as follows: a democratic institution has a polity variable ranging from 6 to 10, an autocratic institution has a polity variable ranging from -6 to -10, and an anocratic institution ranges from -5 to 5.

Table 2.2 Main regression result

	(1) Ln (GDP /Capita)	(2) Ln (GDP /Capita)	(3) Ln (GDP /Capita)	(4) Ln (GDP /Capita)	(5) Ln (GDP /Capita)	(6) Ln (GDP /Capita)	(7) Ln (GDP /Capita)
Treatment Effect	-0.027	0.084	0.101*	0.101*	0.100**	0.102**	0.036
	(0.083)	(0.055)	(0.050)	(0.049)	(0.047)	(0.048)	(0.033)
Labor Productivity		0.943***	0.944***	0.945***	0.915***	0.906***	0.909***
		(0.067)	(0.069)	(0.081)	(0.082)	(0.095)	(0.095)
Polity			-0.005**	-0.005*	-0.006***	-0.007***	
			(0.002)	(0.002)	(0.002)	(0.002)	
Oil Production				0.006	0.009	0.005	0.005
				(0.034)	(0.038)	(0.034)	(0.034)
Investment					0.005	0.000	-0.004
					(0.015)	(0.018)	(0.017)
Opennes						0.034	0.038
						(0.071)	(0.063)
Anocracy							0.074**
							(0.030)
Autocracy							0.033*
							(0.019)
Treatment X Autocracy							0.048
							(0.036)
Treatment X Anocracy							0.183***
							(0.035)
R-squared	0.473	0.877	0.879	0.879	0.873	0.874	0.877
Observations	690	653	638	635	577	577	584

Clustered Standard errors at country level in parentheses
* $p < 0.10$, ** $p < 0.05$***, $p < 0.01$

$$= \quad + \quad + \quad + \quad + \quad * \quad + \quad * \quad + \quad +$$

$$+ \tag{2.3}$$

With this model, I can estimate the impact of changes in democratic, autocratic, and anocratic institutions in which the democratic institution point estimate is , the autocratic institution is + , and the anocratic institution is + . I can also generate the joint hypothesis standard error (+ and +) to test the significance of the result.

The regression result for this model is shown in Table 2.2 specification 7 and can be interpreted as shown in Table 2.3. The result shows that the changes in oil governance have a positive impact on domestic aggregate income for all political institutions. However, the magnitude of the impact is different for different political institutions. The changes of oil governance in non-democratic institutions (autocratic and anocratic institutions) have a positive and significant impact on aggregate domestic income, but the impact is not significant in democratic institutions.

Table 2.3 Treatment effect in democratic, autocratic and anocratic institutions

	Point Estimate
Treatment effect in democratic institution	0.036 (0.033)
Treatment effect in autocratic institution	0.084*** (0.025)
Treatment effect in anocratic institution	0.219*** (0.041)

Clustered Standard errors at country level in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

One plausible explanation of this finding can be drawn from studies of the risk of expropriation in the oil industry (Bohn and Deacon, 2000; Guriev et al., 2011). These works have shown theoretically and empirically that risk of expropriation shapes investment incentive. Moreover, Guriev et al. argued that the risk of expropriation is higher in governments with less checks and balances. Therefore, in a democratic institution, the risk of expropriation is already low enough that changes in oil governance, which arguably lower the risk of expropriation, have a marginal impact on investment incentive.

As a further robustness check, I increase the average contribution of oil and gas rent to GDP threshold to 10% (i.e. I drop countries whose percentage of contribution from oil and gas rent to GDP is less than 10%). As shown in Table A.1 in the Appendix, magnitude of the impact of changes in oil governance is even larger. This results might suggest that the impact of changes in oil governance is also contingent on the importance of oil and gas sector to country's economy.

To further explore this hypothesis, I divide observations in my sample such that the treatment group countries are divided at the median of average contribution from oil and gas rent to GDP. I create oil contribution dummy variable I which is equal to 1 for countries whose average contribution from oil and gas rent to GDP is below the median and In for those countries above the median. Then, I employ another econometric model which includes interaction terms between treatment dummy and oil contribution dummy In and In (equation 2.4).

$$= \quad + \quad + \quad + \quad * \ \mathrm{In} \quad + \quad * \ \mathrm{In} \quad + \qquad (2.4)$$

The result (see Table A.2 in the Appendix) shows that magnitude of the impact of changes in oil governance is larger and significant for countries whose contribution from oil and gas rent to their economy are above the median. Thus, it confirms the hypothesis that the impact of changes in oil governance is also contingent on the importance of oil and gas sector to country's economy.

2.5 Conclusion

This paper aims to empirically investigate the impact of changes in oil governance on aggregate domestic income by employing the difference-in-difference method. Empirical evidences from the difference-in-difference method suggest that oil-producing countries which change the rights given to their NOC (i.e., from ownership rights to only access rights) by enacting laws that create a separate regulatory entity and establishing the NOC merely as a business entity (i.e., only be given access rights to explore and produce like other oil companies) increase their aggregate domestic income around 10%. These results are statistically significant at the 90% and 95% level and robust to various specifications and changes in average oil and gas rent contribution to GDP threshold. From further exploration I also find that the impact is contingent on political institution, with the increase in aggregate domestic income due to changes in oil governance being higher in autocratic and anocratic institutions. The magnitude of the impact of changes in oil governance is also contingent on the importance of oil and gas contribution to country's economy. The magnitude is larger and significant for countries whose average oil and gas contribution to their GDP are above the median. These empirical evidences also suppot Rajan and Zingales' (1998) theory that withholding ownership rights and allocating access rights to all agents is a superior mechanism to granting ownership rights to one agent.

CHAPTER 3

CHANGES IN INSTITUTIONAL DESIGN AND LEARNING-BY-DOING: AN EMPIRICAL STUDY OF OFFSHORE EXPLORATION DRILLING IN SOUTH EAST ASIA

Empirical evidences of learning spillover which is consequential in sustaining an increase in efficiency have been found in various learning-by-doing literatures. However, none of these empirical evidences have been found in oil and gas industry sector. By observing a new dataset on offshore exploration drilling efficiency in the South East Asia region, this chapter provides empirical evidences of learning-by-doing and learning spillover which is influenced by changes in institutional design of oil governance.

3.1 Introduction

Since the seminal work of Arrow (1962), learning-by-doing (i.e., an increase in efficiency or a decrease in unit cost with an increase in experience) has received significant interests in the economics literature. Thompson (2010, 2012) point out several reasons behind these interests. Learning-by-doing is considered a source of economic growth and has distinct consequences to firm behavior which can be influenced by appropriate policy intervention. Moreover, learning-by-doing is also supported with a large empirical literature. Wright (1936) study on cost and quantity relationship in aircraft manufacturing motivates many empirical studies on learning-by-doing in various industries. More recent studies (see Argote, Beckman and Epple (1990), Benkard (2000), Irwin and Klenow (1994), Thornton and Thompson (2001), Conley and Udry

(2010) and Levitt, List and Syverson (2013)) find empirical evidence of the learning-by-doing not only from the firm’s own experience but also from other firms’ experience, which is termed “learning spillover”. Learning spillover is important to sustain an increase in efficiency or productivity. Thornton and Thompson (2001) point out that since learning is bounded, it is efficient for learning to be transferred to another firm.

In the oil and gas industry, Kellogg (2011), Osmundsen et al. (2012), and Redlinger (2015) find empirical evidence of learning-by-doing in Texas, Norwegian Continental Shelf and Bakken, respectively. However, none of these studies find learning spillover. Kellogg (2011) argues that due to the common pool problem in oil and gas extraction, oil and gas companies can make their learning proprietary and therefore prevent learning spillover.

By employing a new dataset on exploration drilling in the South East Asia region, which has a different oil governance structures from the areas examined in the above-mentioned studies, this study investigates the impact of a change in institutional design on the learning-by-doing and particularly on the learning spillover. In 2002, Indonesia changed the institutional design of its oil and gas sector (oil governance) by enacting Law No. 22/2001, which created a separate regulatory entity (BPMIGAS) from the national oil company (Pertamina). The main task of BPMIGAS was to regulate the upstream oil and gas sector by entering and managing production sharing contracts (PSC) with oil companies, including Pertamina. Thurber, et. al. (2011) argue that the separate regulatory entity has the ability to capture knowledge from oil companies and create a learning spillover (or positive knowledge externalities) across oil companies. However, they do not provide empirical evidence to support this. Therefore, this paper aims to answer the following research question: Do changes in institutional design enhance learning-by-doing by an agent and the learning spillover across agents?

By employing an econometric model which contains an interaction term between an institutional design dummy and learning variables, this study finds that a change in institutional design enhances learning-by-doing specific to the rig as well as learning spillover across oil companies within a basin[7]. After a separate regulatory entity was created in Indonesia at year of 2002, a doubling in cumulative drilling by the rig reduces the number of days needed to drill one meter of a well by 24.1%, and a doubling of cumulative drilling in a basin reduces the time to drill one meter of a well by 18.7%. These results are statistically significant and robust to various model specifications.

This study has two primary contributions to the literature. First, it contributes to the learning-by-doing literature by being the first to provide empirical evidence of the impact of changes in institutional design on the learning-by-doing and learning spillover in the oil and gas industry. The empirical evidence provided by this study is important because it shows that an appropriate policy (i.e. the enactment of law which creates separate regulatory entity from national oil company) can influence learning spillover.

Second, this study will also contribute to the oil governance literature. From further exploration in econometric modelling, this study builds an inference on how the learning spillover in a basin is created which support the argument proposed by Thurber, et. al. (2011). Bigger size firms which have more superior experience than smaller firms learn from their own experience in a basin. The regulatory entity captures the knowledge created by bigger firms and creates spillover effects to smaller firms.

---

[7] A basin is a bowl-shaped depression in the earth's crust where sediment accumulates.

The result is important particularly to oil producing countries who want to sustain its oil production. To replace depleted reserves due to production, it is vital to conduct exploration drilling. Since the level of exploration drilling activity will depend on the unit cost, then policy which can influence learning-by-doing and learning spillover is important parts of sustaining oil production. This is particularly true of offshore exploration drilling, which is very expensive. Average day rate for a drill ship rig is US$450,000 whereas a land rig is about US$22,000.

The remainder of the paper will proceed as follows. In section 3.2, I will provide a brief explanation of the oil governance structure in the South East Asia region, agents that are involved in drilling activity and learning opportunities that can increase efficiency. In section 3.3, I will explain my econometric model and data. In section 3.4, I will identify potential problems that might bias my results. In section 3.5, I will describe my results, and in section 3.6, I will provide concluding remarks.

3.2 Oil Governance, Agents in Drilling and Learning Opportunities

Most countries in the South East Asia region (not including Thailand and Cambodia) develop their oil and gas resources through PSCs with oil companies. In a PSC, ownership of the resources (including reserve, facilities and data) is held by the government but can be conveyed to a regulatory entity or a national oil company depending on the institutional design. An oil company working under a PSC will bear all the cost associated with oil and gas production but be reimbursed fully through a cost recovery mechanism. Due to this cost recovery mechanism, oil companies need to have their work program (including their drilling program) and budget approved by the regulatory entity or national oil company before they can proceed with the work. Since Indonesia changed its oil governance in 2002, these approval processes are done by the regulatory entity and not the national oil company.

Through this approval, both the regulatory entity and the national oil company have the ability to capture knowledge and create positive learning spillover across oil companies working in a basin or a country. However, the regulatory entity has a greater incentive to do so. Since the regulatory entity does not explore and produce like a national oil company, it can only increase efficiency in the sector by creating learning spillover across oil companies. In Indonesia, BPMIGAS created a bigger organization to handle the evaluation and approval process of the oil company's activities (including drilling). Pertamina handled this evaluation and approval process through a division, whereas BPMIGAS handled it with a department which consists of several divisions. Moreover, BPMIGAS recruits experienced personnel from oil companies to fill positions within BPMIGAS and hence increase the ability to create a positive learning spillover. These facts support the hypothesis that a change in institutional design (i.e., the creation of separate regulatory entity) would further enhance the spillover effect across agents/companies.

With regard to oil governance, there are three primary agents involved in offshore exploration drilling: drilling rig companies (rig), oil operator companies (operator), and the regulatory entity or national oil company. Drilling rig companies own the rig facility and manage the crew. They are the actual drillers of the well and work based on the drilling program developed by the oil companies. Oil companies own the access rights to explore and produce in an oil block. They develop drilling programs and budgets and seek approval from the regulatory entity or national oil company that owns the resources. They also oversee the drilling operation by the drilling rig companies. The regulatory entity or national oil company will evaluate and approve the drilling program and budget.

The objective of drilling, as pointed out in the petroleum and economics literature (see Kaiser and Pulsipher (2007), Kaiser (2009) and Kellogg (2011)) is to maximize drill rate (a proxy for drilling efficiency) subject to constraints such as geology, technology, physical capability of the rig, and safety requirements. Further, Kellogg (2011) shows that oil firms maximize their drill rate by making optimal drilling decisions. As agents in drilling gain experience, they will gain knowledge that will bring them closer to optimal drilling decision. Thus learning can increase drilling efficiency.

Table 3.1 Learning opportunities by an agent or in an area

Agent/Area	Learning Opportunities
Rig	□ Team performance □ Capacity and performance of the rigs
Operator - Rig	□ Operator drilling procedure □ Knowledge of the most suitable drilling facility for the drilling process
Operator	Management of exploration team
Operator – Basin	Geologic conditions
Basin	Knowledge gained by other operators in a basin
Operator – Country	□ Weather conditions □ Logistical challenges □ Knowledge of country's health, safety and exploration drilling regulation
Country	Knowledge gained by other operators in a country

There are many learning opportunities that can increase drilling efficiency with experience. Osmundsen et al. (2015) provide a comprehensive discussion of these learning opportunities, which I further divide into learning opportunities specific to the agent (rig or operator) or area (basin or country) and relationship-specific learning opportunities between the agent and another agent or within an area (operator – rig, operator – basin, operator – country).

These are shown in Table 3.1 above. In my empirical estimation, I will be able to capture the learning-by-doing effect specific to an agent or the learning spillover within a basin or a country by controlling relationship-specific learning.

3.3 Econometric Model

To test the hypothesis of the impact of institutional design changes to the learning-by-doing and learning spillover, I observe offshore exploration drilling data from the South East Asia region over the time span 1992-2012. Data are sourced from the Wood Mackenzie Upstream Data Tool and consist of 2192 observations from 653 rigs and 258 oil companies in 67 basins and 8 countries. Summary statistics of the observation are shown in Table 3.2 on the next page. I will explore summary statistics in the Identification section

My econometric model (equation 3.1 & 3.2) follows previous learning-by-doing literature particularly in the oil and gas industry (Kellogg 2011; Redlinger 2015) which is a log-log model with log of inverse drill rate (days/meters) as the dependent variable. Kellogg (2011) argues that using drill rate as a proxy for efficiency is a superior method to using unit cost because unit cost varies by rig rates and material prices and is prone to measurement error. I depart from their model by adding an interaction term in which all experience variables interact with a dummy variable , which represents changes in institutional design and is equal to 1 for observations in Indonesia after 2002.

$$\ln(\quad) = \ln\ h(\ ) + \ln\ h(\ ) \quad + \quad + \quad + \quad + \quad + \quad + \quad +$$

$$+ \quad + \qquad (3.1)$$

where:

$$\ln h(\ ) = \ln(\ ) + \ln(\ ) + \ln(\ ) + \ln(\ ) + \ln(\ ) + \ln(\ ) + \ln(\ ) \qquad (3.2)$$

Table 3.2 Summary Statistics

	Ind-Control Before 2002	Ind-Control after 2002	Control Before-after	Indonesia Before-after	Diff-in-diff
Drill rate (days/1000 m)	-6.97 (6.00)	-8.34 (6.10)	-3.29 (3.00)	-4.66 (3.41)	-1.37 (2.02)
Rig Experience	2.49 (0.79)	0.38 (0.54)	-3.44 (0.41)	-5.55 (0.86)	-2.11 (2.20)
Basin Experience	-0.64 (1.31)	-12.00 (1.07)	-2.83 (0.95)	-14.19 (1.41)	-11.36 (1.70)
Operator Experience	14.23 (1.53)	-3.55 (1.14)	-4.06 (0.91)	-21.84 (1.68)	-17.78 (1.91)
Country Experience	121.71 (1.32)	58.46 (1.93)	14.42 (1.28)	-48.83 (1.96)	-63.25 (2.34)
Rig -Operator Exp	3.18 (0.62)	-1.42 (0.29)	-2.02 (0.32)	-6.61 (0.61)	-4.59 (0.69)
Rig - Basin Exp	9.07 (0.88)	-2.59 (0.40)	-1.97 (0.40)	-13.63 (0.88)	-11.67 (0.97)
Rig - Country Exp	12.34 (0.89)	-4.80 (0.45)	0.09 (0.45)	-17.04 (0.89)	-17.14 (1.00)
Measured Depth	-321.75 (58.17)	-252.40 (96.02)	117.83 (47.03)	187.18 (101.94)	69.35 (112.16)
Water Depth	105.89 (18.15)	246.56 (43.69)	94.14 (13.49)	234.81 (45.35)	140.67 (47.26)

As described in section 3.2 above, learning opportunities can be divided into seven groups. Therefore, there are seven experience variables in my model. Three of these experience variables are types of relationship-specific learning: experience of operator o in basin b ( ), operator o in country c ( ), and operator o with rig r ( ). By controlling for relationship-specific learning, I will be able to capture evidence of the learning spillover within basin and country through the coefficient of experience in basin b ( ), and in country c ( ). I will also be able to capture evidence of learning specific to rig and operator through the coefficient of experience by rig r ( ) and by operator o ( ), respectively. All experience variables are before spud date t. I follow Kellogg (2011) in using the cumulative number of wells drilled for the past 2 years as a proxy for experience. Redlinger (2015) shows that using cumulative number of wells as a measure of experience is consistent with studies on drilling efficiency in the petroleum engineering literature and with the learning-by-doing literature, which uses cumulative output as a measure of experience. Furthermore, using the cumulative number of wells drilled in the past 2 years rather than the total cumulative number of wells drilled is also consistent with the organizational forgetting hypothesis (see e.g., Argote, Beckman and Epple (1990) and Benkard (2000)), which posits that recent experience is more important than more-distant experience.

3.4 Identification

To investigate the impact of changes in institutional design to the learning-by-doing and learning spillover, I observe the variation over times and across countries in the South East Asia region and employ an econometric model with interaction terms between the institutional design dummy and various experience variables. Therefore, my method is quite similar to the difference-in-difference method and hence, the model can be justified if the difference-in-difference method assumptions hold. There are two main assumptions in the difference-in-difference method. First, treatment must be exogenous. Second, in the absence of treatment, there are no differences in the trends between treatment group and control group.

The exogeneity of the treatment can be explained by looking at the history of discussion on the changes in Indonesia's oil governance. The discussion was started after Indonesia hosted APEC (Asia Pacific Economy Cooperation) in 1994 but it was halted several times and finally, the Oil and Gas Law was approved after Indonesia started to work with IMF. Therefore, looking at the event that triggered the discussion and the enactment of the law, the 2002 changes in oil governance in Indonesia were part of economic globalization which was trending worldwide and thus it is exogenous to oil and gas industry problems in Indonesia.

To confirm the second assumption, I check for differences in drill rate between the treatment group and control group before Indonesia changed its oil governance in 2002 (or treatment). As shown in Figure 3.1 below, there are hardly any changes in the difference of drill rate between Indonesia and the control group before treatment. Hence, the second assumption holds.

Further, I also check whether the observable characteristics of the control group remain stable before and after treatment. Ideally, they should remain stable, which would suggest that the treatment is not affecting the control group. However, as shown in Table 3.2 above, this is not the case. I argue that the driver of the changes in observable characteristics is not treatment but geological difficulty. Level of exploration drilling would be highly influenced by geological difficulty which is exogenous to the treatment. As shown in Table 3.2 above, exploration drillings in the control group are moving toward deeper water and deeper wells; this is even more so in Indonesia. These statistics show that the geological difficulty in both groups is increasing but even more so in Indonesia. Rig, operator and basin experience is decreasing in the control group and even more in Indonesia. However, the decrease is not driven by the treatment. If the treatment, which arguably increases investment incentive, drives the changes in experience variables, then country's experience in Indonesia should increase and country's experience in the control group should decrease. Therefore, since the observations are showing the contrary (i.e., country's experience in Indonesia is decreasing and country's experience in the control group is increasing) then the driver is not treatment, but geological difficulty. This condition would strengthen regression results because it can confirm that the learning is not the result of an increase in experience which is driven by the treatment effect.

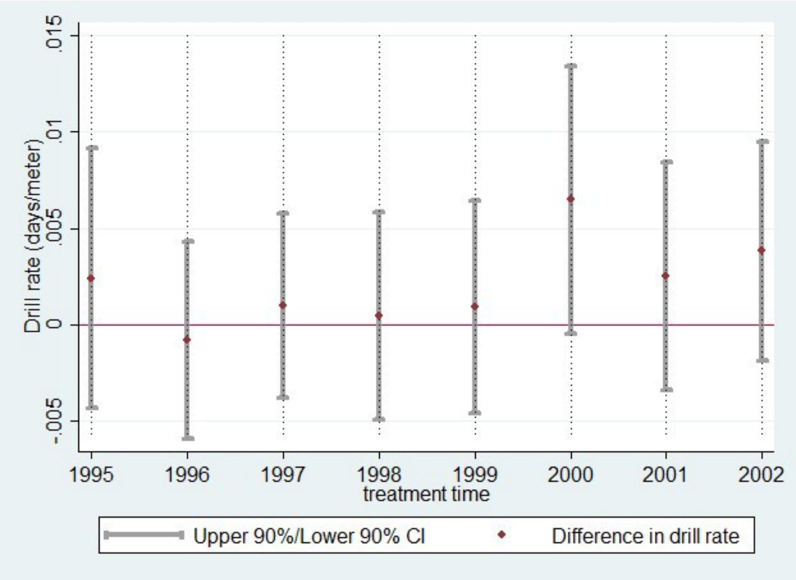

Figure 3.1 Difference in drill rate between Indonesia and control group before and after treatment

Kaiser and Pulsipher (2007) and Kaiser (2009) point out that there are many factors affecting drill time and cost, some of which are observable and some of which are unobservable. Therefore, to avoid omitted variable bias, I control for time-invariant unobserved variables by including rig, basin, operator and country (, , ,) fixed effect. Year and month fixed effect (,) is also employed to control variables which varies by year (e.g. oil price, technology and etc) and by season (e.g. weather). I also include control variables to control for observed variables which might be correlated with drilling efficiency. I include measured depth (MD), MD squared, water depth and also some dummy variables to control for different results of the well, the status of the well, type of the well, offshore type of the well, and rig type. Further, I use cumulative discovery in a basin to control for depletion effect. The reason is that as point out by Osmundsen et al. (2015), cumulative drilling has been used both as an indicator for experience and as an indicator for depletion and therefore, the coefficients of various experience which show learning effects might be confounded by depletion effects. I also check for collinearity between my independent variables through VIF value. As a general rule of thumb, one should concern for multicollinearity if VIF value is above 10. I find that there should be no concern for multicollinearity as there is no VIF value above 10.

3.5 Result

Regression results using equation 3.1 are shown in Table 3.3. The reference case specification which has all the available control variables including depletion effect (shown in column 1) shows that changes in institutional design increase the learning-by-doing effect by rig and spillover effects within a basin.

The coefficient for the interaction term of the dummy variable with the rig experience variable is negative and statistically significant at the 95% level. The marginal effect of rig experience on drilling efficiency after the treatment is the sum of the rig experience variable and the interaction term variables (see Table 3.4). This coefficient shows that changes in institutional design affect learning-by-doing by rig such that a doubling increase in experience of the rig reduces drilling days needed to drill a meter of well by 24.1%; this result is statistically significant at the 95% level. One plausible explanation for this result is that BPMIGAS, which also approves the rig procurement process, can create competition among rigs that enhances learning-by-doing by rig.

The coefficient for the interaction dummy with the basin experience variables is also negative and statistically significant at the 95% level. The marginal effect of basin experience to drilling efficiency after the treatment is the sum of the basin experience variable and the interaction term variables (see Table 3.4). This coefficient also shows that changes in institutional design affect the learning spillover across oil companies within a basin. This effect reduces drilling days needed to drill one meter of a well by 18.7% with a doubling increase in experience in a basin.

Specifications (1) to (7) in Table 3.3 show that the results do not change after changing the control variables. Further, Specification (1) and (2) differ only by cumulative discovery in a basin to control for the depletion effect. The result shows that after controlling for the depletion effect, the impact of institutional design changes on learning-by-doing by the rigs and learning spillover in a basin is larger, which suggests that cumulative discovery in a basin is a good proxy for the depletion effect. To tackle possible group-wise heteroskedasticity, I clustered the standard errors by well, block, basin, and operator. The results are also robust with changes in all standard error clustering (see Table 3.5).

As a further robustness check, to create a more homogenous institutional design, I drop countries whose contracts are not PSC (i.e., Thailand and Cambodia). The result (shown in Table B.1 and Table B.2 in the Appendix) still holds: The coefficient for the interaction term of the dummy variable with the rig experience and the basin experience variables are negative and statistically significant.

Table 3.3 Main Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rig Experience	-0.077**	-0.074**	-0.093***	-0.094***	-0.095***	-0.096***	-0.097***
	(0.03)	(0.031)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Basin Experience	-0.007	-0.001	0.010	0.010	0.011	0.008	0.010
	(0.04)	(0.038)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Operator Experience	0.022	0.009	0.011	0.002	0.003	0.002	0.003
	(0.05)	(0.047)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Country Experience	0.088	0.093*	0.095*	0.085	0.085	0.086	0.086
	(0.05)	(0.054)	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)
Treatment Dummy	-0.735	-0.816	-1.117	-1.481	-1.483	-1.584	-1.555
	(2.00)	(1.988)	(2.073)	(2.075)	(2.077)	(2.083)	(2.080)
Rig Exp. X Treatment Dummy	-0.164**	-0.158**	-0.169**	-0.150**	-0.150**	-0.146**	-0.148**
	(0.07)	(0.072)	(0.072)	(0.070)	(0.070)	(0.070)	(0.070)
Basin Exp. X Treatment Dummy	-0.180**	-0.166*	-0.167*	-0.174*	-0.176**	-0.176**	-0.176**
	(0.09)	(0.086)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)
Operator Exp. X Treatment Dummy	-0.027	-0.025	-0.018	0.014	0.013	0.016	0.020
	(0.11)	(0.113)	(0.119)	(0.121)	(0.121)	(0.121)	(0.121)
Country Exp. X Treatment Dummy	0.246	0.256	0.342	0.415	0.416	0.435	0.429
	(0.42)	(0.422)	(0.439)	(0.441)	(0.441)	(0.442)	(0.442)
Fixed Effect[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Depletion Effect	Yes	No	No	No	No	No	No
Well Result Dummy	Yes	Yes	No	No	No	No	No
Well Status Dummy	Yes	Yes	Yes	No	No	No	No
Well Type Dummy	Yes	Yes	Yes	Yes	No	No	No
Offshore Type Dummy	Yes	Yes	Yes	Yes	Yes	No	No
Rig Type Dummy	Yes	Yes	Yes	Yes	Yes	Yes	No
N	2178	2178	2192	2192	2192	2192	2192

[a] Fixed effects include rig, basin, operator, country, year and month

Robust Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.4 Marginal effect of rig and basin experience to drilling efficiency after treatment

	Coefficient
Rig Experience Marginal Effect	-0.241*** (0.072)
Basin Experience Marginal Effect	-0.187** (0.087)

Robust Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 3.5 Regression result with standard error clustered by well, basin operator and block.

	(1)	(2)	(3)	(4)
Rig Experience	-0.077** (0.031)	-0.077** (0.030)	-0.077** (0.030)	-0.077** (0.037)
Basin Experience	-0.007 (0.038)	-0.007 (0.041)	-0.007 (0.036)	-0.007 (0.045)
Operator Experience	0.022 (0.047)	0.022 (0.047)	0.022 (0.057)	0.022 (0.053)
Country Experience	0.088 (0.054)	0.088 (0.065)	0.088 (0.075)	0.088 (0.082)
Treatment Dummy	-0.735 (1.997)	-0.735 (2.326)	-0.735 (3.117)	-0.735 (2.413)
Rig Experience X Treatment Dummy	-0.164** (0.072)	-0.164*** (0.054)	-0.164** (0.081)	-0.164** (0.068)
Basin Experience X Treatment Dummy	-0.180** (0.086)	-0.180** (0.080)	-0.180** (0.080)	-0.180** (0.082)
Operator Experience X Treatment Dummy	-0.027 (0.113)	-0.027 (0.112)	-0.027 (0.125)	-0.027 (0.134)
Country Experience X Treatment Dummy	0.246 (0.423)	0.246 (0.484)	0.246 (0.651)	0.246 (0.503)
Clustered standard error by	well	basin	operator	block
Observations	2178	2178	2178	2178

Clustered Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Further, to remove heterogeneity in the size of oil companies, I also run a regression with only oil companies who are drilling more than 5 wells in the past 2 years, and the result (shown in Table B.3 and Table B.4 in Appendix) still holds. However, the significance of the learning spillover in a basin is lost and in some specifications (specification (3) to (7)) the coefficient for experience of operator in a basin is negative and statistically significant. This result might suggest that a bigger oil company learns more from its own experience than from others. Hence, the learning spillover in a basin found in main regression results above might be driven by small oil company.

To further investigate this hypothesis which infers from regression results with only big oil companies, I employ another econometric model (equation 3.3) by adding second interaction term between size of oil companies dummy ($_{n1}$ and equal to 1 for oil companies who are drilling more than 5 wells in the past 2 years), institutional design dummy (and equal to 1 for Indonesia after 2002) and experience variables to the previous econometric model.

$$\ln(\qquad) = \ln h(\;) + \qquad + \ln h(\;) \qquad + \quad {}_{n1} \quad +$$

$$\ln h(\;) \qquad {}_{n1} \; + \qquad + \quad + \quad + \quad + \quad + \quad + \quad + \qquad (3.3)$$

The marginal effects of various experiences on small size oil company’s drilling efficiency after the treatment are now the sum of the various experience variable and the first interaction term variables which only include institutional design dummy. For big size oil company, the marginal effects after the treatment are the sum of small size oil company’s marginal effects after the treatment and second interaction term which include institutional design dummy and size of oil companies dummy. Regression results are shown in Table B.5 and Table B.6 at the Appendix from which I calculate marginal effect of various experience variables of interest after the treatment as shown in Table 3.6

Table 3.6 Marginal effect of various experiences to drilling efficiency after treatment

	Oil Companies Size	Coefficient
Rig Experience Marginal Effect	Small	-0.272* (0.146)
	Big	-0.260*** (0.090)
Basin Experience Marginal Effect	Small	-0.216** (0.096)
	Big	0.183 (0.176)
Operator - Basin Exp. Marginal Effect	Small	-0.233 (0.203)
	Big	-0.407** (0.175)
Country Exp. Marginal Effect	Small	0.199 (0.421)
	Big	-0.138 (0.427)

Robust Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The result which is shown in Table 3.6 below confirm regression results which only include big oil companies (shown in Table B.3 and Table B.4). After Indonesia changed its oil governance, big oil companies reduce time to drill a well by learning from their own experience in a basin (shown by a negative and statistically significant coefficient on operator in a basin experience variable) whereas small oil companies reduce time to drill a well by learning for other oil companies working in a basin (shown by a negative and statistically significant coefficient on basin experience).

With this result, I can build an inference on the mechanism of learning spillover. Big oil companies who have more experience than small oil companies learn from their own experience in a basin. The regulatory entity captures the knowledge created by big oil companies and creates spillover effect to small oil companies.

3.6 Conclusion

This paper aims to empirically investigate the impact of policy intervention that changed institutional design (i.e., the creation of a separate regulatory entity) to the learning-by-doing and learning spillover in the oil and gas industry. The regulatory entity which is created by the changes in institutional design has a greater incentive to capture knowledge created by oil companies and to create positive learning spillover across oil companies. The results of this analysis show that enactment of a law in 2002 which created a separate regulatory entity (i.e., BPMIGAS) in Indonesia enhances learning-by-doing effect by rig such that a doubling increase in experience reduces days to drill a meter of well by 24.1%. One possible explanation for the increase in the learning-by-doing effect by the rigs is that through procurement approval, BPMIGAS can create competition among rigs.

The creation of regulatory entity also enhances positive learning spillover within a basin such that a doubling increase in experience reduces days needed to drill a meter of well by 18.7%. From further exploration, this study builds an inference on learning spillover mechanism. Big oil companies who have more experience than small oil companies learn from their own experience in a basin. Then, the regulatory entity captures the knowledge created by big oil companies and creates spillover effect to small oil companies. The result is important because it show that policy which creates separate regulatory entity from national oil company enhances learning-by-doing and learning spillover. It can provide guidance to government in oil producing countries who is on the lookout for an appropriate policy to sustain its oil production by increasing efficiency through learning.

CHAPTER 4

CHANGES IN INSTITUTIONAL DESIGN, EXPROPRIATION RISK AND EXTRACTION PATH

Economic theory shows that the impact of expropriation risk on the extraction path of non-renewable resources is ambiguous and therefore the solution is available in the empirics. By employing producing field-level data in the South East Asia region, this chapter observes empirically the impact of a change in institutional design of oil governance in Indonesia on expropriation risk and extraction path.

4.1 Introduction

Over-extraction of natural resources can cause many problems. In petroleum engineering literature, extraction above critical flow rates can cause damage to the reservoir due to water coning[8] which would incur higher extraction cost and even incomplete depletion of the reservoir. Technically, over-extraction by private firms even with some possible reductions in future production performance is possible if there is enough economic incentive. If the economic incentives to private firms causes extraction above social time of preference, then the resource will be depleted faster than socially preferred. This is the essence of a concern which was raised by Solow (1974, p.8). By referring to the Hotelling (1931) model[9], he writes "If it is true that

---

[8] In the petroleum engineering literature, critical flow rate has been discussed thoroughly (see Høyland et al. (1989), Kuo (1983) and studies which cite them). Kuo (1983) points out that field engineers need to find the critical flow rate, and if production above the critical rate is necessitated by economic influence they need to find out the water coning time and performance of the well after water coning.

[9] In the standard Hotelling (1931) model, higher discount rates tilt production to the present and lead to faster depletion.

the market rate of interest exceeds the social rate of time preference, then scarcity rents and market prices will rise faster than they "ought to" and production will have to fall correspondingly faster along the demand curve. Thus the resource will be exploited too fast and exhausted too soon”. In the economics literature, one of the economic incentives which can cause over-extraction by private firms is uncertainty on the ownership of extraction due to expropriation risk[10]. Oil firms which face uncertainty due to expropriation risk[11] may incorporate it by raising their risk-adjusted discount rate.

This problem can get even more complicated because in more recent theoretical models, the impact of expropriation risk on extraction path is ambiguous (see Neher (1981), Lassare (1982), Farzin (1984), Olsen (1987) and Bohn and Deacon (2000)) and depends on the capital intensity of the extraction process and size of the resource stock. Therefore, an effort to reduce expropriation risk can also cause higher extraction rate and lead to faster depletion. This is particularly concerning in countries which are endowed with few natural resources[12]. Since the impact of expropriation risk on extraction path is theoretically ambiguous, this paper is interested in empirically investigating the impact of reducing the expropriation risk due to a change in institutional design of oil governance on the extraction path.

Notably, Bohn and Deacon (2000) and Olsen (2013) conducted empirical studies of the impact of expropriation risk on the extraction path of the exhaustible resource[13]. They investigate

---

[10] Common pool resources can also cause over-extraction (See Aivazian and Callen (1979)). However, in my dataset common pool resource is not a problem because the government owns the resources.

[11] Expropriation risk can be defined broadly as any act of government that can curtail private firms’ claim on their income from an investment project, including capital levies, unexpected taxes or even nationalization. However, to be consistent with the theory in which model expropriation risk is a 0 or 1 event, the term “expropriation risk” in this paper is interchangeable with the term “threat of nationalization.”

[12] This concern is raised by Farzin (1984).

[13] There are some other empirical papers on determinants of expropriation (Guriev et al (2011), Stroebel and Van Benthem (2013), Mahdavi (2014).

capital intensity as a source of ambiguity on the impact of expropriation risk on the natural resource extraction path. However, to the extent of my knowledge, there has been no study investigating resource stocks as a source of ambiguity, though these have been shown theoretically as a plausible source. Therefore, by observing a change in the institutional design of oil governance in Indonesia which arguably reduced expropriation risk, I aim to answer the following research question: what is the impact of reduction in expropriation risk on the extraction path for different sizes of resource stock?

This essay makes two primary contributions. First, it will contribute to the oil governance literature by providing empirical evidence of how changes in oil governance affect expropriation risk. By employing a difference-in-difference econometric model, I can make an inference that the change in oil governance reduces expropriation risk and causes oil companies to choose a slower extraction path. Second, it will contribute to the exhaustible resource extraction literature by providing empirical evidence of another source of ambiguity in determining the impact of expropriation risk on oil extraction path: the size of resource stocks. Regression results show that the impacts of the reduction in expropriation risk are different for different sizes of resource stocks. Specifically, reduced expropriation risk causes oil companies to choose a slower extraction path for smaller resources. My results reiterate the importance of strengthening institutions to influence the extraction path such that over-extraction can be avoided and a more sustainable extraction path can be achieved.

To answer the research question posed above, the remainder of this essay will be structured as follows. In section 4.2, I will provide a discussion of how the change in institutional design of oil governance can reduce expropriation risk and affect the extraction path. In section 4.3, I will discuss an econometric model. In section 4.4, I will identify potential problems that might affect my results, which will be described in section 4.5. I will provide concluding remarks in section 4.6.

4.2 Change in oil governance, risk of expropriation and extraction path

In order to extract oil and gas, governments of oil-producing countries typically work with oil and gas companies who have the technological, labor and capital capabilities to explore and to produce oil and gas. Depending on the institutional design, the government appoints a National Oil Company (NOC) or a government entity to hold a bidding round, to award an oil and gas contract and then to monitor and regulate it. In 1971, Indonesia created a NOC named Pertamina[14]. As the NOC, Pertamina not only explored and produced from its own oil and gas fields but also was appointed to do the tasks listed above. Since the creation of Pertamina, oil companies that wanted to work in Indonesia had to enter into an oil and gas contract scheme, called a Production Sharing Contract (PSC), with Pertamina.

Driven by worldwide trends in economic globalization, Indonesia changed its institutional design of oil governance in 2002, creating a separate regulatory entity called BPMIGAS so that Pertamina had to act only as a business entity (i.e., only to explore and produce from its own fields) similar to other oil companies. The task of BPMIGAS was to replace Pertamina in managing and regulating PSCs. Since the creation of BPMIGAS, oil companies (including Pertamina) enter into PSCs with BPMIGAS (i.e., the contracting party in the PSC switches from Pertamina to BPMIGAS). This switch of the contracting party in the PSC from Pertamina, which is also an oil company (i.e., possessing the technological, labor and capital capability to explore and produce in an oil field), to a separate regulatory entity arguably

---

[14] Hertzmark (2007) provides a thorough discussion on Pertamina.

increases the cost of expropriation and reduces expropriation risk.

Stroebel and Van Benthem (2013) argue that due to incomplete information about the cost of expropriation, even in an optimal contract, expropriation is a possible event with positive probability. The probability is even higher when the benefit of expropriation to the government exceeds the cost of expropriations. Therefore, the occurrence of expropriation is more likely at high oil prices or in countries with low cost of expropriations. Hence, oil governance in which oil companies are making contracts with the NOC rather than with a separate regulatory entity has a higher expropriation risk because the cost to expropriate is lower. Unlike a NOC, a separate regulatory entity does not have the technological, labor and capital capability to take over the operation after the expropriation. The state entity can appoint the NOC (or other oil company) to take over the operation, but there will be a time gap to transfer knowledge and assets, which incurs an opportunity cost to the government. Therefore, the change in oil governance increases the cost of expropriation and reduces expropriation risk. However, the impact of the change in oil governance on the extraction path is ambiguous because in theory, the impact of reducing the expropriation risk on the extraction path is unclear.

The impact of expropriation risk on oil extraction path was formalized by Long (1975) and can be explained with simplicity using the Hotelling (1931) model. If oil firms face uncertainty due to expropriation risk, they may incorporate it by raising their risk-adjusted discount rate. A higher discount rate causes oil extraction to be tilted to the present and eventually causes faster depletion. However, these models[15] do not include capital, which is an

---

[15] Capital was first introduced as a factor in non-renewable extraction by Campbell (1980). He shows that under certainty, investing in the beginning (at time t = 0) is always optimal and extraction is always at capacity for some period of time.

important characteristic in oil and gas extraction.

Oil and gas extraction is a capital-intensive sector. Prior to extraction, capital is required to find reserves (exploration drilling, seismic, geological & geophysical study, etc.) and to develop them (production facility, pipeline, development drilling, etc.). When capital is introduced into the theoretical model, the impact of expropriation risk on extraction path can become ambiguous (see Neher (1981), Lassare (1982), Farzin (1984), Olsen (1987) and Bohn and Deacon (2000)). Intuitively, higher risk-adjusted discount rate reduces the value of the resource stock in the ground, which causes faster extraction. However, it also increases the cost of capital, which causes slower extraction due to under-investment. Therefore, the oil extraction path is affected by two opposing forces of expropriation risk. It can follow the standard Hotelling rule or the inverse Hotelling rule. If the direct effect of the expropriation risk dominates the indirect effect through investment, it will follow the standard Hotelling rule (i.e., higher discount rate will cause firms to choose higher extraction rate). If the indirect effect of the expropriation risk dominates the direct effect, it will follow the inverse Hotelling rule (i.e., higher discount rate will cause firms to choose slower extraction rate).

Neher (1981), Lassare (1982), Farzin (1984) and Olsen (1987) show that the ambiguity of the impact of expropriation risk on the extraction path depends on capital intensity and the size of the resource stock. They basically show that, for a large enough resource stock, the capital intensity term will dominate the size of the resource stocks term such that reduction in expropriation risk leads to a faster extraction path (inverse Hotelling rule). It is vice versa for small enough resource stocks: the size of the resource stocks term will dominate the capital intensity term such that a reduction in expropriation risk leads to slower extraction (standard Hotelling rule). Since the impact of reduction in expropriation risk on the extraction path is theoretically ambiguous, the problem is empirical.

4.3 Econometric model

To empirically study the impact of a change in the institutional design of oil governance on expropriation risk and extraction path, I observe producing oil and gas fields in the South East Asia region during the period of 1996 – 2012. I source the dataset from IHS which consists of 5688 observations of field-level oil and gas production, recoverable & in-place reserves (proven and probable), number of development drilling projects, production start year and some other field characteristics from 620 fields, 55 basins and 9 countries. Observations start in 1996 mainly because data on the number of development drilling projects, which is an important control variable, is not reliable prior to that year.

In estimating the relationship between how the change in oil governance impacts expropriation risk and extraction path, I use a difference-in-difference method. This method is powerful in estimating the impact of a policy provided that it is possible to observe some fields characteristics prior to and after implementation of the policy for groups that are affected by the policy (treatment group) and are not affected by the policy (control group). In this paper, my treatment group is all producing oil and gas fields in Indonesia after 2002. The control group is other fields in the South East Asia region. Since my dataset covers the period prior to and after the change in oil governance in Indonesia for the treatment group and the control group, the difference-in-difference method can be employed. The challenge of this method is that it requires that some underlying assumptions hold. These assumptions will be discussed in the identification section. My difference-in-difference model is:

$$= \quad + \quad + \quad + \quad + \tag{4.1}$$

The dependent variable is oil and gas extraction rate at field i, country c and year t, following previous literature (Bohn and Deacon (2003) and Olsen (2013)) in using log of production to reserve ratio (log(l /1)) as a proxy. Olsen (2013) points out since higher and lower oil and gas extraction rates will intersect at some point in time t (as shown in Figure C.1 in the Appendix) then the relative speed of extraction will depend on the time t when the observation is made. After the intersection time t, a relatively faster extraction path will become slower and vice versa. Therefore, using oil and gas production by itself as a proxy for extraction rate is not appropriate. Using a formal proof, Olsen (2013) shows that using the production to reserve ratio will solve this problem (i.e., faster/slower extraction path will be independent of time). Since number of development drilling projects (a proxy for capital), which is an important control variable, cannot be differentiated between oil and gas wells, I sum oil and gas production as the numerator in the extraction rate variable. To do that, I convert gas production from mscf (million standard cubic feet) of gas to BOE (Barrel of Oil Equivalence) using a conversion factor (6 scf = 1 BOE). For the denominator in the extraction rate, I calculate the reserve at field i, country c and year t using recoverable reserve and in-place reserve data[16]. Since the reserves from producing field data is isolated from the exploration effect (i.e., a new commercial discovery will be developed under a new field), then oil and gas reserve at year t (1) can be calculated as the initial recoverable or in-place reserve (1) minus cumulative production before year t (1 = 1 − Σ l). The consequence of this calculation is that I need to drop fields whose production data are not starting from the beginning (year 1) of their production because the cumulative production is not correct. I also drop fields whose reserve is negative at

---

[16] Recoverable reserve will be used in the main estimation, and in-place reserve will be used as a robustness check.

some year t because this condition indicates that cumulative production is bigger than initial reserve, which is also not correct.

My independent variables consist of my variable of interest, which is oil governance dummy ( ) and time varying control variables ( ) which consist of a proxy for the depletion effect and log capital to reserve ratio. I also included year ( ) and field ( ) fixed effects because they are necessitated by the difference-in-difference model and they capture unobserved variables which vary by years (price, technology, etc.) and time-invariant unobserved variables which vary by fields (geological condition, geographical condition, etc.), respectively. My dummy variable captures the impact of the change in oil governance; it is equal to 1 for all oil and gas producing fields in Indonesia each year after 2002 and equal to 0 otherwise. As a proxy for the depletion effect, I choose to use number of years in production instead of cumulative production[17] because number of years in production is not affected by treatment and is correlated with the extraction path (as shown in Figure C.2 and Figure C.3 in the Appendix). As a proxy for flow of capital, I use number of development drilling projects, which is more preferable than other types of capital such as production facilities for two main reasons. First, a production facility is typically built before the start of production (i.e., up-front capital) unless there is a modification or the field is developed in phases, whereas development drilling is spread out across production years (as shown in Figure C.4 in the Appendix). Therefore, development drilling is more suitable to be used in a panel setting. Second, using a physical measure (number of drilling projects) rather than cost is less prone to measurement error. To avoid taking the log of zero which will result in missing observations, I scale up the number of

---

[17] Bohi and Toman (1984) point out that cumulative production is a good proxy to capture the depletion or stock effect.

development drilling projects by adding one to all development drilling observations.

4.4 Identification

The reliability of the difference-in-difference estimate depends on two important assumptions. First, the difference between the treatment and control groups does not change in the absence of treatment (i.e., both groups must have the same trend prior to treatment). Second, the treatment is exogenous.

I test the first assumption by determining if prior to treatment, the treatment and control groups have the same trend. This assumption is tested by employing a model:

$$= {}_{\mathrm{l}} + \quad + \quad + \; \Sigma^{n} \qquad + \Sigma \qquad + \tag{4.2}$$

This model can capture the differences in extraction rate between the treatment and control groups in the pre-treatment period (parameter) and post-treatment period (parameter). The differences (shown in Figure 4.1) confirm that prior to treatment, there are no significant differences between the treatment and control groups, and a significant break exists after treatment. One would be concerned that there is an upward trending before the treatment. However, since the trend before treatment is in a different direction from the trend after treatment, the trend is not concerning and hence, the first assumption is valid.

With regard to the second assumption, the main driver of the change in oil governance in Indonesia was economic globalization which was trending worldwide. Discussion about oil and gas law in Indonesia was only triggered after Indonesia hosted the Asian Pacific Economic Cooperation (APEC) in 1994. The discussion was halted several times, but after working with the IMF, Indonesia finally enacted the Oil and Gas Law in 2002. Therefore, looking at the event which initiated the discussion and the enactment of the Oil and Gas Law, the treatment is exogenous.

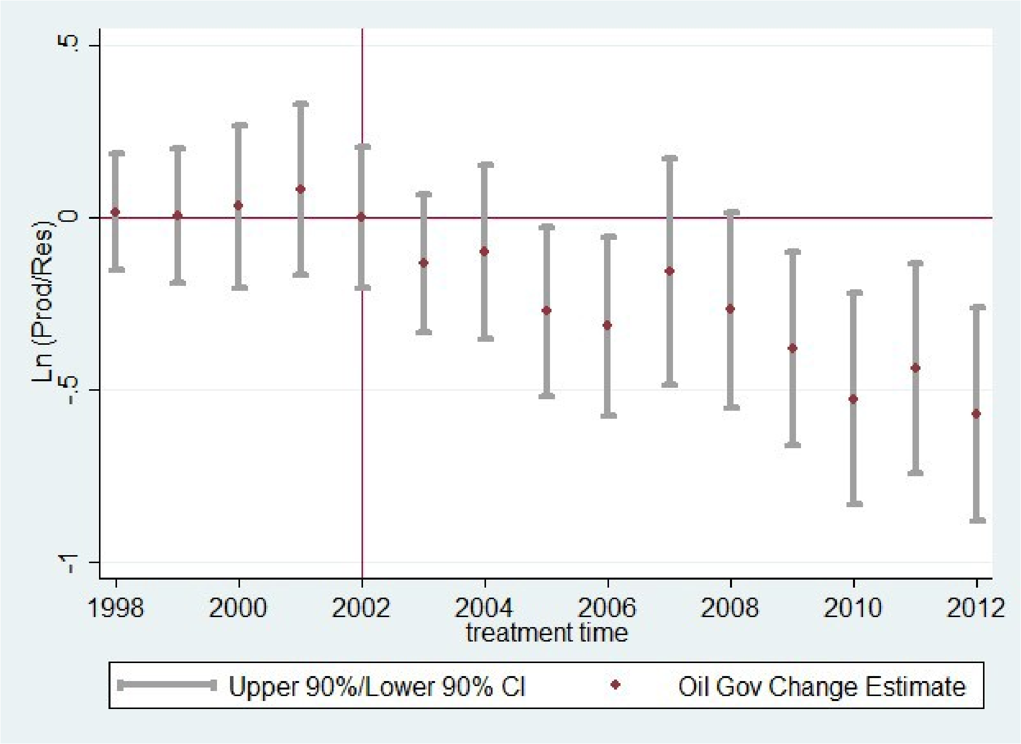

Figure 4.1 The differences in extraction paths between treatment and control groups in pre-treatment and post-treatment periods

Another problem which might bias the result of an empirical model analyzing the supply behavior of exhaustible resources is aggregation bias[18]. Many empirical models use aggregated data,[19] but the theory is built on an individual/firm level. The problem is not merely consistency between the theoretical and empirical models; aggregating across individuals with different characteristics can be particularly problematic in non-renewable extraction. Fields are different in their reserve size and geological characteristics, and firms are different in their technological,

---

[18] See Bohi and Toman (1984) chapter 6 for a thorough discussion of aggregation bias on non-renewable supply model.

[19] Bohn and Deacon's (2000) empirical model also uses aggregate data at the country level.

labor and capital capabilities. Therefore, each firm will have different responses to changes in conditions (price, depletion effect, regulations, etc.) depending on their characteristics. Thus, my econometric model which uses producing field-level data can provide a more reliable estimate of the response of oil companies to the change in oil governance. Moreover, by using producing field-level data, I can isolate the impact from exploration since new commercial discovery will be developed under new fields. Hence, I can also overcome the interdependency problem between exploration and production, another criticism which is pointed out by Bohi and Toman (1984).

4.5 Results

The main regression results from the difference-in-difference method are shown in Figure 4.1. The coefficient of the oil governance dummy variable in specification 1 and 2 is negative and statistically significant, even after controlling for the depletion effect. From these two specifications, it is clear that the change in oil governance causes oil companies to choose a slower extraction path. However, the mechanism is still not clear because I cannot infer the impact of the change in oil governance to expropriation risk. Therefore, in specifications 3 to 8, I control for the indirect effect of expropriation risk by controlling for capital. I control not just for the current flow of capital but also for the lagged effect of flow of capital (in an effort to account for installation lag). I also try to control for stock of capital by using the cumulative number of development drilling projects in the past 3 years[20]. By controlling for the indirect effect of expropriation risk, the coefficient for the oil governance dummy now only captures the direct effect of expropriation risk. The coefficient is negative and statistically significant at the 99%

---

[20] I assume that after 3 years, development wells have been fully depreciated.

confidence level, which shows that the direct effect of expropriation risk causes oil firms to choose a slower extraction path. Since there is no ambiguity in the direct effect of the expropriation risk (i.e., reduction in expropriation risk leads to slower extraction path), I can infer from these results that the change in oil governance reduces the expropriation risk. Thus, from specification 1 and 2 results, I can also make an inference that the reduction in expropriation risk decreases the extraction rate by roughly 40% or decreases the production to reserve ratio from 6%[21] to 3.6% which significantly increases production life of the fields.

All results are consistent with theory which shows that for small enough resource stocks, the impact of reduction in expropriation risk will follow the standard Hotelling rule (i.e., direct effect dominates indirect effect such that reduction in expropriation risk leads to slower extraction path). I will further confirm this result later in this section by employing another econometric model which includes an interaction term between the oil governance dummy and the size of reserve dummy, but first I am going to explain some interesting results for the control variables.

The coefficients of the control variables for flow of capital, lag of flow of capital and stock of capital are positive and statistically significant at the 99% confidence level. These results show that an increase in flow (current or lag) or stock of capital leads to an increase in extraction rates. These results make intuitive sense as the more wells are drilled, the higher the extraction rate of the field.

---

[21] In my dataset, average production to reserve ratio is 6%.

Table 4.1 Main regression results

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.397***	-0.388***	-0.392***	-0.383***	-0.305***	-0.298**	-0.369***	-0.360***
Dummy	(0.136)	(0.136)	(0.133)	(0.133)	(0.117)	(0.117)	(0.121)	(0.121)
Depletion		0.037***		0.032***		0.008		0.024***
effect[a]		(0.010)		(0.009)		(0.008)		(0.009)
Flow of			0.085***	0.084***				
capital[b]			(0.026)	(0.026)				
Lag flow of					0.185***	0.184***		
capital[b]					(0.026)	(0.026)		
Stock of							0.264***	0.264***
capital[c]							(0.029)	(0.029)
Observations	5688	5632	5688	5632	5323	5276	5667	5611

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling projects in the past 3 years/reserve

The coefficient for the depletion effect in all specifications except specification 6 is positive and statistically significant at the 99% confidence level, which shows that as the number of years in production increase, the higher the extraction rate of the field. These results seem counterintuitive because the extraction rate is supposed to be declining over years of production. This intuition can also be confirmed from a scatter plot of extraction rates from all fields (shown in Figure C.2). However, by plotting the extraction rate from some random fields (shown in Figure C.3), the extraction path in an individual field is not just declining over time but has a bell shape. Therefore, as a robustness check, I include the square function of the depletion effect in the model (results are shown in Table C.1in the Appendix). The coefficient is negative and statistically significant for the quadratic term and is positive and statistically significant for the linear term, which confirms the bell shape of the individual field extraction paths. More importantly, the coefficients for the oil governance change dummy are still robust.

To further investigate the impact of reduction in expropriation risk at different reserve sizes, I employ another econometric model which includes an interaction term between the oil governance dummy and the size of reserve dummy:

$$= \quad + \quad + \quad + \quad + \quad * \ 11111 \quad + \quad * \ 11111 \quad +$$

$$11111 \quad + \quad 11111 \quad + \qquad\qquad (4.3)$$

I define fields whose reserve in 2001[22] is below the 25th percentile as small reserve fields, between the 25th and 75th percentile as medium reserve fields and above the 75th percentile as large reserve fields. With this model, I can estimate the impact of reduction in expropriation risk in small, medium and large reserve fields. The marginal effect for a small reserve field is , for a medium reserve field is $+$ and for a large reserve field is $+$. I will also generate the joint hypothesis standard error ($+$ and $+$) to test the significance of the result.

The regression results for this model are shown in Table 4.2, and the marginal effects for small, medium and large reserves are shown in Table 4.3. In Table 4.2, the coefficient for the interaction term between the oil governance change dummy and small reserve fields is negative and statistically significant, whereas coefficient for the interaction term between the oil governance change dummy and medium reserve fields is positive and statistically significant. It

---

[22] I choose reserve in 2001 as the base reserve to divide the fields into 3 percentile groups because reserve in this year is not affected by the change in oil governance.

is even more positive and statistically significant for the interaction term between the oil governance change dummy and large reserve fields. These results show that the extraction rate for large reserve fields is faster than for medium reserve fields, and the extraction rate for medium reserve fields is faster than for small reserve fields. The marginal effect (shown in Table 4.3) shows that reduced expropriation risk causes oil companies to choose a slower extraction path for medium reserve fields but not as slow as for small reserve fields. More importantly, the impact of reduction in expropriation risk on extraction path is not significant for large reserve fields because the indirect effect through capital investment offsets the direct effect. In theory, though it is not shown in my empirical results, for a large enough reserve, a reduction in expropriation risk can cause oil firms to choose a faster extraction path (i.e., the coefficient flips to positive). To summarize the results from the model with interaction terms between the oil governance change dummy and the size of reserve dummy, the impact of reduction in expropriation risk is different for different sizes of reserve. Specifically, the extraction path is slower for smaller reserve fields.

To test the robustness of the main regression results, I provide some different ways in standard error clustering and also some alternative specifications to the econometric model. First, I clustered standard error at field, basin and country level to tackle possible group-wise heterokedasticity. As shown in Table C.2, Table C.3 and Table C.4 in the Appendix, the results are robust to these different ways in standard error clustering.

Second, one might be concerned that the results are driven by new fields whose production started after the change in oil governance in 2002. Since new fields might have a low production to reserve ratio, they might drive the regression results to show a slower extraction path. Therefore, as a further robustness check, I dropped fields whose production started after

2002. The results are still robust (see Table C.5 in the Appendix). All the coefficients are still following the same sign as the main regression results and are statistically significant.

Table 4.2 Regression results from model with an interaction term between oil governance change dummy and size of reserve fields.

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)
Oil Gov Change Dummy	-0.585***	-0.587***	-0.598***
	(0.152)	(0.153)	(0.151)
OGC Dummy X Med Res	0.203*	0.223**	0.229**
	(0.111)	(0.112)	(0.114)
OGC Dummy X Large Res	0.404***	0.403***	0.460***
	(0.138)	(0.140)	(0.140)
Linear term depletion effect[a]		0.037***	0.061***
		(0.010)	(0.013)
Quadratic term depletion effect[a]			-0.001***
			(0.000)
Observations	5688	5632	5632

Robust Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
[a] proxy by number of years in production

Third, Olsen (2013) points out that using recoverable reserve data might be problematic because they might be affected by expropriation risk. By definition, recoverable reserve is the part of a physical reserve which it is economically viable to extract. Therefore, expropriation risk which theoretically can influence economic incentive might affect recoverable reserve data. As a further robustness check I use in-place reserve, which is a more physical measure of reserve than recoverable reserve. The results show that all the coefficients get larger but are still following the same sign as the main regression results and are statistically significant (see Table C.6 in the Appendix)

Table 4.3 Marginal effect of the impact of reduction in expropriation risk on different-sized reserves

	Ln (Prod/Res)
Oil Gov Change Dummy	-0.598***
	(0.151)
OGC Dummy X Med Res	-0.369***
	(0.141)
OGC Dummy X Large Res	-0.138
	(0.160)

Robust Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Lastly, the reserve calculation might introduce endogeneity into the model. As mentioned above, the dependent variable ( ) is log of production to reserve ratio (log(l /1)), which is equal to log of production (log(l)) minus log of reserve (l 1(1) = l 1(1 – Σ l)). If log of reserve is moved to the right-hand side of the main econometric model (Equation 4.1), the model might contain a lag effect of the dependent variable which might be correlated with the error term. Hence, as a final robustness check, I follow Olsen (2013) in using the log of production to fixed reserve (measure at some year t) ratio. He shows that by using the fixed reserve, the behavior of the relative speed of extraction does not change (i.e., it is still independent of the time of observation) as long as the fixed reserve observation is made after the production observations. Fortunately, in my model, fixed reserve will be controlled automatically through the field fixed effect so that my model will only include the log of production as a dependent variable. The results (shown in Table C.7 in the Appendix) show that the coefficient of the oil governance change dummy is still negative and statistically significant, which confirms the robustness of the results.

4.6 Conclusion

Expropriation risk can be reduced by a change in the institutional design of oil governance which creates a separate regulatory entity whose task is to take on the role of a NOC in managing and regulating PSCs. By controlling for the indirect effect of the change in expropriation risk through capital, the regression results show that the direct effect causes oil firms to choose a slower extraction path. Since there is no ambiguity in the direct effect of reduction in expropriation risk, I can infer that the change in oil governance reduces expropriation risk. The impact of the reduction in expropriation risk is different for different sizes of reserves in that the extraction path is slower for smaller reserve fields. These results are robust to some alternative specifications and different ways in standard error clustering. They confirm the theory that if the resource stock is small enough, the extraction path will follow a standard Hotelling model rule (i.e., reduction in expropriation risk results in a slower extraction path and vice versa). Thus, the results reiterate the importance of strengthening institutions to influence the extraction path even in a country endowed with small resource stocks such that over-extraction can be avoided and a more sustainable extraction path can be achieved.

CHAPTER 5

CONCLUSION

The impact of the changes in oil governance on aggregate domestic income, learning-by-doing and learning spillover effect as well as on expropriation risk and extraction has been explored empirically in this dissertation. Results from the first essay show that a country that changed its oil governance by enacting a law that creates a separate regulatory entity such that NOC is merely a business entity increases its aggregate domestic income around 10%. From further exploration we also find that the impact is contingent on political institution and on contribution to the country's income from the oil and gas sector such that the increase in GDP is higher in countries with non-democratic institutions and whose oil and gas contribution to the country's economy is high. The results basically confirm the economic theory which shows that withholding ownership rights and allocating access rights to all agents is a superior mechanism to granting ownership rights to one agent.

The second essay argues that the separate regulatory entity has greater incentives to increase efficiency by creating learning spillover. Regression results show that creation of a separate regulatory entity enhances learning-by-doing by the rigs and learning spillover across oil companies working in a basin. From further exploration, this study can build an inference on the learning spillover mechanism. Big oil companies that have more exploration drilling experience than small oil companies learn from their own experience in a basin. Then, the regulatory entity captures the knowledge created by big oil companies and creates a spillover effect to small oil companies

In the third essay, I argue that the creation of a separate regulatory entity whose task is to replace the role of the NOC in managing and regulating the oil and gas sector increases the cost of expropriation and hence reduces expropriation risk. From the regression results, I can infer that the change in oil governance reduces expropriation risk. Further, the impact of the reduction in expropriation risk is different for different sizes of reserves in that the extraction path is slower for smaller reserve fields. Results from this essay confirm the theory that for small enough resource stocks the impact of expropriation risk on extraction path follows a standard hoteling rule (i.e., reduction in expropriation risk leads to slower extraction path and vice versa). All empirical evidence which is provided in this dissertation shows the importance of strengthening the institutional design of oil governance such that efficiency can be increased, expropriation risk can be reduced, over-extraction can be avoided and more sustainable economic welfare can be achieved.

REFERENCES

Aivazian, V. A., & Callen, J. L. (1979). A note on the economics of exhaustible resources. The Canadian Journal of Economics/Revue Canadienne d'Economique, 12(1), 83-89.

Argote, L., Beckman, S. L., & Epple, D. (1990). The persistence and transfer of learning in industrial settings. Management Science, 36(2), 140-154.

Arrow, K. J. (1962). The economic implications of learning by doing. The Review of Economic Studies, 29(3), 155-173.

Benkard, C. L. (2000). Learning and forgetting: The dynamics of aircraft production. The American Economic Review, 90(4), 1034-1054.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? The Quarterly Journal of Economics, 119(1), 249-275.

Bohi, D. R., & Toman, M. A. (1984). Analyzing Nonrenewable Resource Supply, Resources for the Future. ISBN, 915707055, 10-41.

Bohn, H., & Deacon, R. T. (2000). Ownership risk, investment, and the use of natural resources. American Economic Review, 526-549.

British Petroleum. (2014). Statistical review of world energy, June 2014.

Brunnschweiler, C. N., & Valente, S. (2013). Property rights, oil and income levels: Over a century of evidence.

Campbell, H. F. (1980). The effect of capital intensity on the optimal rate of extraction of a mineral deposit. The Canadian Journal of Economics/Revue Canadienne d'Economique, 13(2), 349-356.

Conference Board Total Economy Database™, January 2014, http://www.conference-board.org/data/economydatabase/

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. The American Economic Review, 100(1), 35-69.

Cust, J., & Harding, T. (2014). Institutions and the location of oil exploration (No. 127). Oxford, UK: Oxford Centre for the Analysis of Resource Rich Economies, University of Oxford.

Doppelhofer, G., Miller, R. I., Huang, K. X., Liu, Z., Phaneuf, L., Engelmann, D., ... & Engel, E. M. (2004). Determinants of long-term growth: A Bayesian Averaging of Classical Estimates (BACE) approach. American Economic Review, 94(4), 813-835.

Eller, S. L., Hartley, P. R., & Medlock III, K. B. (2011). Empirical evidence on the operational efficiency of National Oil Companies. Empirical Economics, 40(3), 623-643.

Energy Information Administration. (2014). Country analysis. Available from http://www.eia.gov/countries/

Farzin, Y. H. (1984). The effect of the discount rate on depletion of exhaustible resources. The Journal of Political Economy, 841-851.

Grayson, L. E. (1981). National oil companies. John Wiley & Sons.

Guriev, S., Kolotilin, A., & Sonin, K. (2011). Determinants of nationalization in the oil sector: A theory and evidence from panel data. Journal of Law, Economics, and Organization, 27(2), 301-323.

Hartley, P., & Medlock, K. B. (2008). A model of the operation and development of a National Oil Company. Energy Economics, 30(5), 2459-2485.

Hertzmark, D. (2007). Pertamina: Indonesia's State-Owned Oil Company. Rice University.

Heston, A., & Summers, R. (2012). Bettina Aten (2012): Penn World Table Version 7.1. Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.

Hotelling, H. (1931). The economics of exhaustible resources. The Journal of Political Economy, 137-175.

Høyland, L. A., Papatzacos, P., & Skjaeveland, S. M. (1989). Critical rate for water coning: Correlation and analytical solution. SPE Reservoir Engineering, 4(04), 495-502.

Irwin, D. A., & Klenow, P. J. (1994). Learning-by-doing spillovers in the semiconductor industry. Journal of Political Economy, 102(6), 1200-1227.

Kaiser, M. J. (2009). Modeling the time and cost to drill an offshore well. Energy, 34(9), 1097-1112.

Kaiser, M. J., & Pulsipher, A. G. (2007). Generalized functional models for drilling cost estimation. SPE Drilling & Completion, 22(02), 67-73.

Kellogg, R. (2011). Learning by drilling: Interfirm learning and relationship persistence in the Texas oilpatch. The Quarterly Journal of Economics, qjr039.

Kuo, M. C. T. (1983). A simplified method for water coning predictions. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers.

Lasserre, P. (1982). Exhaustible-resource extraction with capital. In Natural Resources Conference, Vancouver.

Levitt, S. D., List, J. A., & Syverson, C. (2013). Toward an understanding of learning by doing: Evidence from an automobile assembly plant. Journal of Political Economy, 121(4), 643-681.

Mahdavi, P. (2014). Extortion in the oil states: Nationalization, regulatory structure, and corruption. UCLA manuscript.

Mahdavi, P. (2014). Why do leaders nationalize the oil industry? The politics of resource expropriation. Energy Policy, 75, 228-243.

Marshall, M. G., Jaggers, K., & Gurr, T. R. (2010). Polity IV Project: Political Regime Characteristics and Transitions, 1800-2010.

Mideksa, T. K. (2013). The economic impact of natural resources. Journal of Environmental Economics and Management, 65(2), 277-289.

Neher, P. A. (1982). RENT-A-RIG. Australian Economic Papers, 21(38), 170-176.

Olsen, E. H. (2013). Expropriation risk and natural resource extraction: A matter of capital intensity. Retrieved from https://www.duo.uio.no/handle/10852/35718

Olsen, T. E. (1987). Resource extraction and capital investments under uncertainty. Resources and Energy, 9(3), 209-222.

Osmundsen, P., Roll, K. H., & Tveteras, R. (2012). Drilling speed—the relevance of experience. Energy Economics, 34(3), 786-794.

Osmundsen, P., Roll, K. H., & Tveteras, R. (2012). Drilling speed—the relevance of experience. Energy Economics, 34(3), 786-794.

Pérez-González, F. (2005). The impact of acquiring control on productivity. Working Paper Columbia University.

Rajan, R. G., & Zingales, L. (1998). Power in a theory of the firm. Quarterly Journal of Economics, 387-432.

Redlinger, M. (2015). Drilling down the Bakken Learning Curve. Division of Economic and Business CSM Working Paper Series, No. 2015-04.

Smith, B. (2015). The resource curse exorcised: Evidence from a panel of countries. Journal of Development Economics, 116, 57-73.

Solow, R. (1974). The Economics of Resources or the Resources of Economics. American Economic Review, 64(2), 1-14.

Stevens, P. (2008). National oil companies and international oil companies in the Middle East: Under the shadow of government and the resource nationalism cycle. The Journal of World Energy Law & Business, 1(1), 5-30.

Stroebel, J., & Van Benthem, A. (2013). Resource extraction contracts under threat of expropriation: Theory and evidence. Review of Economics and Statistics, 95(5), 1622-1639.

Thompson, P. (2010). Learning by doing. Handbook of the Economics of Innovation, 1, 429-476.

Thompson, P. (2012). The relationship between unit cost and cumulative quantity and the evidence for organizational learning-by-doing. The Journal of Economic Perspectives, 26(3), 203-224.

Thornton, R. A., & Thompson, P. (2001). Learning from experience and learning from others: An exploration of learning and spillovers in wartime shipbuilding. American Economic Review, 91(5), 1350-1368.

Thurber, M. C., Hults, D. R., & Heller, P. R. (2011). Exporting the “Norwegian Model”: The effect of administrative design on oil sector performance. Energy Policy, 39(9), 5366-5378.

Van Long, N. (1975). Resource extraction under the uncertainty about possible nationalization. Journal of Economic Theory, 10(1), 42-53.

Victor, D. G., Hults, D. R., & Thurber, M. C. (Eds.). (2011). Oil and governance: state-owned enterprises and the world energy supply. Cambridge, UK: Cambridge University Press.

Wolf, C. (2009). Does ownership matter? The performance and efficiency of state oil vs. private oil (1987–2006). Energy Policy, 37(7), 2642-2652.

Wood Mackenzie (2015). Upstream Data Tools, accessed 11.19.2015

World Bank. (2008). A citizen’s guide to national oil companies, part B: Data directory. Washington, DC.

World Bank. (2014). World development indicator. Retrieved from http://data.worldbank.org/data-catalog/world-development-indicators.

Wright, T. P. (1936). Factors affecting the cost of airplanes. Journal of the Aeronautical Sciences, 3(4), 122-128.

APPENDIX A
CHAPTER 2 SUPPLEMENTAL FIGURE AND TABLE

Table A.1 Difference-in-difference result with 10% average oil and gas rent contribution to GDP threshold

	(1) Ln (GDP /Capita)	(2) Ln (GDP /Capita)	(3) Ln (GDP /Capita)	(4) Ln (GDP /Capita)	(5) Ln (GDP /Capita)	(6) Ln (GDP /Capita)
Treatment Effect	0.030	0.154**	0.162**	0.162**	0.189***	0.195***
	(0.129)	(0.065)	(0.069)	(0.070)	(0.066)	(0.063)
Labor Productivity		0.942***	0.941***	0.946***	0.916***	0.906***
		(0.074)	(0.075)	(0.086)	(0.088)	(0.106)
Polity			-0.003	-0.003	-0.006**	-0.007**
			(0.003)	(0.003)	(0.003)	(0.003)
Oil Production				0.002	0.007	0.003
				(0.035)	(0.039)	(0.034)
Investment					0.003	-0.001
					(0.015)	(0.018)
Opennes						0.035
						(0.090)
R-squared	0.441	0.867	0.868	0.869	0.861	0.862
Observations	575	538	525	522	472	472

Clustered Standard errors at the country level in parentheses
* p < 0.10, ** p < 0.05***, p < 0.01

Table A.2 Difference-in-difference result with interaction term between oil governance change dummy and 2-quantile of oil and gas contribution to GDP dummy

	(1) Ln (GDP /Capita)	(2) Ln (GDP /Capita)	(3) Ln (GDP /Capita)	(4) Ln (GDP /Capita)	(5) Ln (GDP /Capita)	(6) Ln (GDP /Capita)
Treat Dum X Small Oil Rent	-0.074	0.029	0.048	0.048	0.043	0.041
	(0.066)	(0.052)	(0.041)	(0.039)	(0.029)	(0.029)
Treat Dum X Big Oil Rent	0.022	0.142**	0.153**	0.152**	0.181***	0.191***
	(0.124)	(0.063)	(0.068)	(0.069)	(0.062)	(0.060)
Labor Productivity		0.944***	0.944***	0.947***	0.920***	0.908***
		(0.067)	(0.068)	(0.080)	(0.081)	(0.094)
Polity			-0.004*	-0.004*	-0.006***	-0.006***
			(0.002)	(0.002)	(0.002)	(0.002)
Oil Production				0.003	0.005	0.000
				(0.034)	(0.038)	(0.033)
Investment					0.008	0.002
					(0.015)	(0.018)
Opennes						0.042
						(0.071)
R-squared	0.475	0.879	0.880	0.881	0.876	0.877
Observations	690	653	638	635	577	577

Clustered Standard errors at the country level in parentheses
* p < 0.10, ** p < 0.05***, p < 0.01

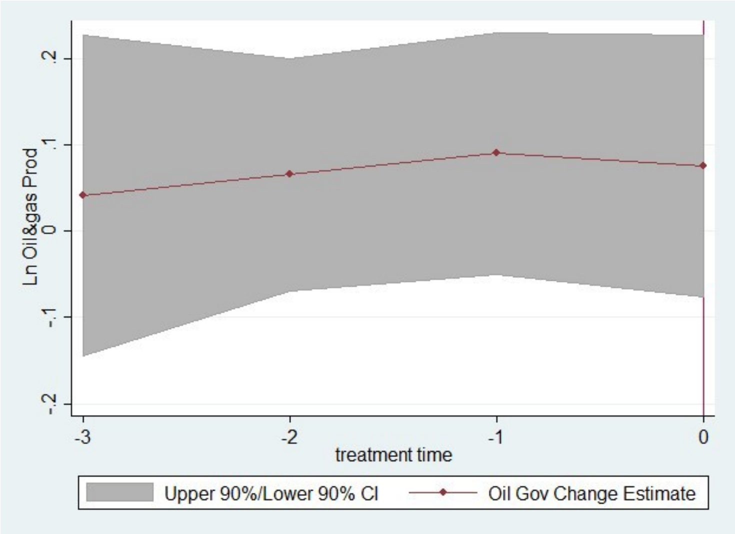

Figure A.1 Log of oil and gas production before treatment

APPENDIX B
CHAPTER 3 SUPPLEMENTAL FIGURE AND TABLE

Table B.1 Regression results after dropping Thailand and Cambodia

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rig Experience	-0.037 (0.041)	-0.037 (0.041)	-0.051 (0.043)	-0.049 (0.043)	-0.053 (0.043)	-0.056 (0.043)	-0.056 (0.043)
Basin Experience	-0.006 (0.045)	-0.007 (0.045)	0.006 (0.047)	0.005 (0.047)	0.009 (0.047)	0.003 (0.047)	0.003 (0.047)
Operator Experience	-0.011 (0.055)	-0.027 (0.056)	-0.032 (0.058)	-0.047 (0.058)	-0.044 (0.059)	-0.047 (0.058)	-0.047 (0.058)
Country Experience	0.035 (0.072)	0.043 (0.071)	0.031 (0.074)	0.020 (0.074)	0.025 (0.074)	0.032 (0.074)	0.032 (0.074)
Treatment Dummy	-2.026 (2.209)	-2.457 (2.195)	-2.632 (2.267)	-3.233 (2.256)	-3.250 (2.259)	-3.381 (2.274)	-3.381 (2.274)
Rig Exp. X Treatment Dummy	-0.179** (0.080)	-0.171** (0.081)	-0.158* (0.083)	-0.144* (0.081)	-0.138* (0.081)	-0.133 (0.081)	-0.133 (0.081)
Basin Exp. X Treatment Dummy	-0.234*** (0.091)	-0.212** (0.091)	-0.180* (0.094)	-0.206** (0.095)	-0.217** (0.095)	-0.213** (0.095)	-0.213** (0.095)
Operator Exp. X Treatment Dummy	-0.077 (0.121)	-0.072 (0.122)	-0.079 (0.125)	-0.049 (0.124)	-0.054 (0.125)	-0.044 (0.124)	-0.044 (0.124)
Country Exp. X Treatment Dummy	0.526 (0.470)	0.599 (0.467)	0.644 (0.482)	0.770 (0.481)	0.779 (0.481)	0.802* (0.484)	0.802* (0.484)
Fixed Effect[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Depletion Effect	Yes	No	No	No	No	No	No
Well Result Dummy	Yes	Yes	No	No	No	No	No
Well Status Dummy	Yes	Yes	Yes	No	No	No	No
Well Type Dummy	Yes	Yes	Yes	Yes	No	No	No
Offshore Dummy	Yes	Yes	Yes	Yes	Yes	No	No
Rig Type Dummy	Yes	Yes	Yes	Yes	Yes	Yes	No
N	2178	2178	2192	2192	2192	2192	2192

[a] Fixed effects include rig, basin, operator, country, year and month
Robust standard errors in parentheses
* $p < 0.10$ ** $p < 0.05$*** $p < 0.01$

Table B.2 Regression results after dropping Thailand and Cambodia with standard error clustered by well, basin operator and block.

	(1)	(2)	(3)	(4)
Rig Experience	-0.037 (0.041)	-0.037 (0.047)	-0.037 (0.050)	-0.037 (0.046)
Basin Experience	-0.006 (0.045)	-0.006 (0.056)	-0.006 (0.060)	-0.006 (0.054)
Operator Experience	-0.011 (0.055)	-0.011 (0.056)	-0.011 (0.060)	-0.011 (0.064)
Country Experience	0.035 (0.072)	0.035 (0.067)	0.035 (0.088)	0.035 (0.106)
Treatment Dummy	-2.026 (2.209)	-2.026 (2.593)	-2.026 (3.595)	-2.026 (2.663)
Rig Experience X Treatment Dummy	-0.179** (0.080)	-0.179** (0.080)	-0.179* (0.094)	-0.179** (0.088)
Basin Experience X Treatment Dummy	-0.234*** (0.091)	-0.234** (0.097)	-0.234*** (0.071)	-0.234*** (0.083)
Operator Experience X Treatment Dummy	-0.077 (0.121)	-0.077 (0.138)	-0.077 (0.130)	-0.077 (0.148)
Country Experience X Treatment Dummy	0.526 (0.470)	0.526 (0.546)	0.526 (0.739)	0.526 (0.548)
Clustered standard error by:	Well	basin	operator	block
Observations	1576	1576	1576	1576

Clustered Standard errors in parentheses
* $p < 0.10$ ** $p < 0.05$*** $p < 0.01$

Table B.3 Regression results with only oil companies who are drilling more than 5 wells in the past 2 years.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rig Experience	-0.081** (0.038)	-0.081** (0.038)	-0.111*** (0.041)	-0.117*** (0.040)	-0.116*** (0.040)	-0.116*** (0.040)	-0.116*** (0.040)
Basin Experience	0.044 (0.053)	0.051 (0.053)	0.032 (0.056)	0.036 (0.057)	0.035 (0.057)	0.034 (0.056)	0.034 (0.056)
Operator - Basin Experience	-0.091** (0.043)	-0.097** (0.043)	-0.085* (0.043)	-0.090** (0.043)	-0.093** (0.043)	-0.091** (0.043)	-0.091** (0.043)
Country Experience	0.024 (0.068)	0.032 (0.068)	0.056 (0.071)	0.047 (0.073)	0.045 (0.073)	0.048 (0.072)	0.048 (0.072)
Rig Exp. X Treatment Dummy	-0.204** (0.102)	-0.195* (0.102)	-0.165* (0.100)	-0.136 (0.095)	-0.136 (0.096)	-0.135 (0.095)	-0.135 (0.095)
Basin Exp. X Treatment Dummy	0.104 (0.251)	0.126 (0.250)	0.309 (0.253)	0.274 (0.256)	0.263 (0.257)	0.260 (0.256)	0.260 (0.256)
Operator - Basin Exp. X Treatment Dummy	-0.408 (0.271)	-0.416 (0.271)	-0.440* (0.266)	-0.468* (0.270)	-0.464* (0.271)	-0.463* (0.271)	-0.463* (0.271)
Country Exp. X Treatment Dummy	-0.320 (0.662)	-0.302 (0.661)	-0.441 (0.677)	-0.373 (0.677)	-0.333 (0.678)	-0.316 (0.676)	-0.316 (0.676)
Treatment Dummy	0.914 (2.991)	0.744 (2.985)	0.998 (3.044)	0.722 (3.029)	0.554 (3.034)	0.480 (3.025)	0.480 (3.025)
Fixed Effect[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Depletion Effect	Yes	No	No	No	No	No	No
Well Result Dummy	Yes	Yes	No	No	No	No	No
Well Status Dummy	Yes	Yes	Yes	No	No	No	No
Well Type Dummy	Yes	Yes	Yes	Yes	No	No	No
Offshore Dummy	Yes	Yes	Yes	Yes	Yes	No	No
Rig Type Dummy	Yes	Yes	Yes	Yes	Yes	Yes	No
N	1562	1562	1576	1576	1576	1576	1576

[a] Fixed effects include rig, basin, operator, country, year and month

Robust standard errors in parentheses

$* p < 0.10$, $** p < 0.05$, $*** p < 0.01$

Table B.4 Regression results with standard error clustered by well, basin operator and block for oil companies who are drilling more than 5 wells in the past 2 years.

	(1)	(2)	(3)	(4)
Rig Experience	-0.087** (0.041)	-0.087* (0.046)	-0.087* (0.048)	-0.087* (0.048)
Basin Experience	0.016 (0.059)	0.016 (0.079)	0.016 (0.064)	0.016 (0.074)
Operator – Basin Experience	-0.091** (0.043)	-0.091*** (0.030)	-0.091** (0.043)	-0.091** (0.044)
Country Experience	0.024 (0.068)	0.024 (0.101)	0.024 (0.094)	0.024 (0.102)
Rig Exp. X Treatment Dummy	-0.204** (0.102)	-0.204** (0.094)	-0.204 (0.134)	-0.204* (0.107)
Basin Exp. X Treatment Dummy	0.104 (0.251)	0.104 (0.227)	0.104 (0.245)	0.104 (0.267)
Operator - Basin Exp. X Treatment Dummy	-0.408 (0.271)	-0.408*** (0.144)	-0.408 (0.317)	-0.408 (0.307)
Country Exp. X Treatment Dummy	-0.320 (0.662)	-0.320 (0.931)	-0.320 (1.044)	-0.320 (0.805)
Treatment Dummy	0.914 (2.991)	0.914 (4.349)	0.914 (4.944)	0.914 (3.771)
Clustered standard error by:	well	basin	operator	block
Observations	1562	1562	1562	1562

Clustered standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table B.5 Regression results with second interaction term

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment Dummy	0.411	0.314	0.007	-0.368	-0.363	-0.390	-0.352
	(1.979)	(1.963)	(2.020)	(2.041)	(2.044)	(2.047)	(2.043)
Rig Exp.	-0.200	-0.198	-0.272*	-0.254*	-0.253*	-0.255*	-0.257*
X Treatment Dummy	(0.144)	(0.145)	(0.142)	(0.144)	(0.144)	(0.144)	(0.145)
Basin Exp.	-0.210**	-0.203**	-0.214**	-0.215**	-0.218**	-0.216**	-0.218**
X Treatment Dummy	(0.094)	(0.094)	(0.102)	(0.103)	(0.104)	(0.103)	(0.103)
Operator - Basin Exp.	-0.191	-0.197	-0.007	-0.011	-0.011	-0.010	-0.020
X Treatment Dummy	(0.205)	(0.205)	(0.228)	(0.224)	(0.224)	(0.224)	(0.224)
Country Exp.	0.114	0.138	0.270	0.338	0.338	0.344	0.334
X Treatment Dummy	(0.424)	(0.420)	(0.429)	(0.433)	(0.434)	(0.435)	(0.434)
Rig Exp.	0.012	0.021	0.132	0.136	0.136	0.141	0.141
X Treatment X Size	(0.165)	(0.165)	(0.159)	(0.161)	(0.161)	(0.162)	(0.163)
Basin Exp.	0.399**	0.426**	0.555***	0.535***	0.540***	0.540***	0.540***
X Treatment X Size	(0.188)	(0.188)	(0.195)	(0.200)	(0.199)	(0.197)	(0.198)
Operator – Basin Exp.	-0.174	-0.186	-0.448	-0.450	-0.454	-0.456	-0.450
X Treatment X Size	(0.259)	(0.260)	(0.277)	(0.278)	(0.278)	(0.278)	(0.278)
Country Exp.	-0.337***	-0.364***	-0.496***	-0.476***	-0.479***	-0.481***	-0.478***
X Treatment X Size	(0.117)	(0.116)	(0.116)	(0.117)	(0.116)	(0.116)	(0.116)
Fixed Effect[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Depletion Effect	Yes	No	No	No	No	No	No
Well Result Dummy	Yes	Yes	No	No	No	No	No
Well Status Dummy	Yes	Yes	Yes	No	No	No	No
Well Type Dummy	Yes	Yes	Yes	Yes	No	No	No
Offshore Type Dummy	Yes	Yes	Yes	Yes	Yes	No	No
Rig Type Dummy	Yes	Yes	Yes	Yes	Yes	Yes	No
N	2171	2171	2186	2186	2186	2186	2186

[a] Fixed effects include rig, basin, operator, country, year and month
Robust standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table B.6 Regression results with second interaction term and standard error clustered by well, basin operator and block

	(1)	(2)	(3)	(4)
Treatment Dummy	0.411 (1.979)	0.411 (2.457)	0.411 (2.989)	0.411 (2.273)
Rig Exp. X Treatment Dummy	-0.200 (0.144)	-0.200* (0.113)	-0.200 (0.139)	-0.200* (0.115)
Basin Exp. X Treatment Dummy	-0.210** (0.094)	-0.210** (0.099)	-0.210* (0.108)	-0.210** (0.105)
Operator - Basin Exp. X Treatment Dummy	-0.191 (0.205)	-0.191 (0.260)	-0.191 (0.203)	-0.191 (0.219)
Country Exp. X Treatment Dummy	0.114 (0.424)	0.114 (0.518)	0.114 (0.642)	0.114 (0.493)
Rig Exp. X Treatment X Size	0.012 (0.165)	0.012 (0.133)	0.012 (0.173)	0.012 (0.143)
Basin Exp. X Treatment X Size	0.399** (0.188)	0.399*** (0.145)	0.399* (0.206)	0.399** (0.197)
Operator - Basin Exp. X Treatment X Size	-0.174 (0.259)	-0.174 (0.305)	-0.174 (0.269)	-0.174 (0.286)
Country Exp. X Treatment X Size	-0.337*** (0.117)	-0.337*** (0.108)	-0.337*** (0.114)	-0.337*** (0.109)
Clustered standard error by:	well	basin	operator	block
Observations	2171	2171	2171	2171

Clustered standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

APPENDIX C
CHAPTER 4 SUPPLEMENTAL FIGURE AND TABLE

Table C.1 Robustness check with quadratic function of depletion effect

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)
Oil Gov Change Dummy	-0.385*** (0.132)	-0.381*** (0.128)	-0.298** (0.116)	-0.358*** (0.114)
Linear term depletion effect[a]	0.059*** (0.013)	0.054*** (0.013)	0.012 (0.011)	0.047*** (0.011)
Quadratic term depletion effect[a]	-0.001*** (0.000)	-0.001*** (0.000)	-0.000 (0.000)	-0.001*** (0.000)
Flow of capital[b]		0.081*** (0.026)		
Lag flow of capital[b]			0.184*** (0.026)	
Stock of capital[c]				0.263*** (0.029)
Observations	5632	5632	5276	5611

Robust Standard errors in parentheses
$* p < 0.10, ** p < 0.05, *** p < 0.01$
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.2 Robustness check by clustering standard error at field level

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.397***	-0.388***	-0.392***	-0.383***	-0.305***	-0.298**	-0.369***	-0.360***
Dummy	(0.136)	(0.136)	(0.133)	(0.133)	(0.117)	(0.117)	(0.121)	(0.121)
Depletion		0.037***		0.032***		0.008		0.024***
effect[a]		(0.010)		(0.009)		(0.008)		(0.009)
Flow of			0.085***	0.084***				
capital[b]			(0.026)	(0.026)				
Lag flow of					0.185***	0.184***		
capital[b]					(0.026)	(0.026)		
Stock of							0.264***	0.264***
capital[c]							(0.029)	(0.029)
Observations	5688	5632	5688	5632	5323	5276	5667	5611

Clustered Standard errors at field level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.3 Robustness check by clustering standard error at basin level

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. chnge	-0.397***	-0.388***	-0.392***	-0.383***	-0.305**	-0.298**	-0.369***	-0.360***
Dummy	(0.139)	(0.139)	(0.132)	(0.132)	(0.139)	(0.138)	(0.112)	(0.113)
Depletion		0.037***		0.032***		0.008		0.024***
effect[a]		(0.011)		(0.011)		(0.011)		(0.009)
Flow of			0.085***	0.084***				
capital[b]			(0.025)	(0.025)				
Lag flow of					0.185***	0.184***		
capital[b]					(0.030)	(0.030)		
Stock of							0.264***	0.264***
capital[c]							(0.038)	(0.038)
Observations	5688	5632	5688	5632	5323	5276	5667	5611

Clustered Standard errors at basin level in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.4 Robustness check by clustering standard error at country level

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.397***	-0.388***	-0.392***	-0.383***	-0.305*	-0.298*	-0.369***	-0.360***
Dummy	(0.104)	(0.103)	(0.094)	(0.094)	(0.139)	(0.139)	(0.059)	(0.059)
Depletion		0.037***		0.032***		0.008		0.024***
effect[a]		(0.010)		(0.009)		(0.012)		(0.005)
Flow of			0.085***	0.084***				
capital[b]			(0.017)	(0.017)				
Lag flow of					0.185***	0.184***		
capital[b]					(0.030)	(0.031)		
Stock of							0.264***	0.264***
capital[c]							(0.036)	(0.037)
Observations	5688	5632	5688	5632	5323	5276	5667	5611

Clustered Standard errors at country level in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.5 Robustness check by dropping fields whose production started after year of 2002

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.388***	-0.388***	-0.381***	-0.381***	-0.300**	-0.300**	-0.360***	-0.360***
Dummy	(0.137)	(0.137)	(0.133)	(0.133)	(0.117)	(0.117)	(0.121)	(0.121)
Depletion		0.028***		0.022**		0.005		0.017*
effect[a]		(0.009)		(0.009)		(0.008)		(0.009)
Flow of			0.114***	0.114***				
capital[b]			(0.028)	(0.028)				
Lag flow of					0.190***	0.190***		
capital[b]					(0.028)	(0.028)		
Stock of							0.258***	0.258***
capital[c]							(0.032)	(0.032)
Observations	4764	4764	4764	4764	4595	4595	4750	4750

Robust Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.6 Robustness check by using in-place reserve instead of recoverable reserve

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.626***	-0.620***	-0.595***	-0.589***	-0.518***	-0.513***	-0.526***	-0.519***
Dummy	(0.131)	(0.131)	(0.127)	(0.128)	(0.114)	(0.114)	(0.115)	(0.115)
Depletion		0.006		0.004		-0.015*		0.002
effect[a]		(0.009)		(0.009)		(0.008)		(0.008)
Flow of			0.132***	0.131***				
capital[b]			(0.026)	(0.026)				
Lag flow of					0.245***	0.246***		
capital[b]					(0.025)	(0.025)		
Stock of							0.307***	0.307***
capital[c]							(0.029)	(0.029)
Observations	5940	5884	5940	5884	5567	5520	5919	5863

Robust Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
[a] proxy by number of years in production
[b] proxy by number of development drilling/reserve
[c] proxy by number of development drilling in the past 3 years/reserve

Table C.7 Robustness check by using fixed reserve

	(1) Ln (Prod/Res)	(2) Ln (Prod/Res)	(3) Ln (Prod/Res)	(4) Ln (Prod/Res)	(5) Ln (Prod/Res)	(6) Ln (Prod/Res)	(7) Ln (Prod/Res)	(8) Ln (Prod/Res)
Gov. change	-0.540***	-0.535***	-0.538***	-0.534***	-0.441***	-0.437***	-0.516***	-0.511***
Dummy	(0.141)	(0.141)	(0.140)	(0.140)	(0.126)	(0.126)	(0.125)	(0.125)
Depletion		-0.018*		-0.019*		-0.045***		-0.029***
effect[a]		(0.010)		(0.010)		(0.009)		(0.009)
Flow of			0.025	0.024				
capital[b]			(0.030)	(0.030)				
Lag flow of					0.134***	0.134***		
capital[b]					(0.029)	(0.029)		
Stock of							0.236***	0.235***
capital[c]							(0.032)	(0.032)
Observations	5688	5632	5688	5632	5323	5276	5667	5611

Robust Standard errors in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

[a] proxy by number of years in production

[b] proxy by number of development drilling/reserve

[c] proxy by number of development drilling in the past 3 years/reserve

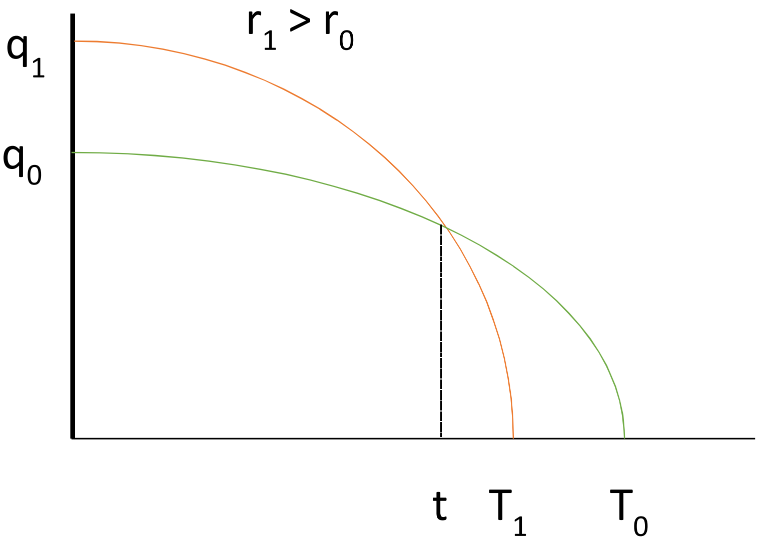

Figure C.1 Extraction path under expropriation risk

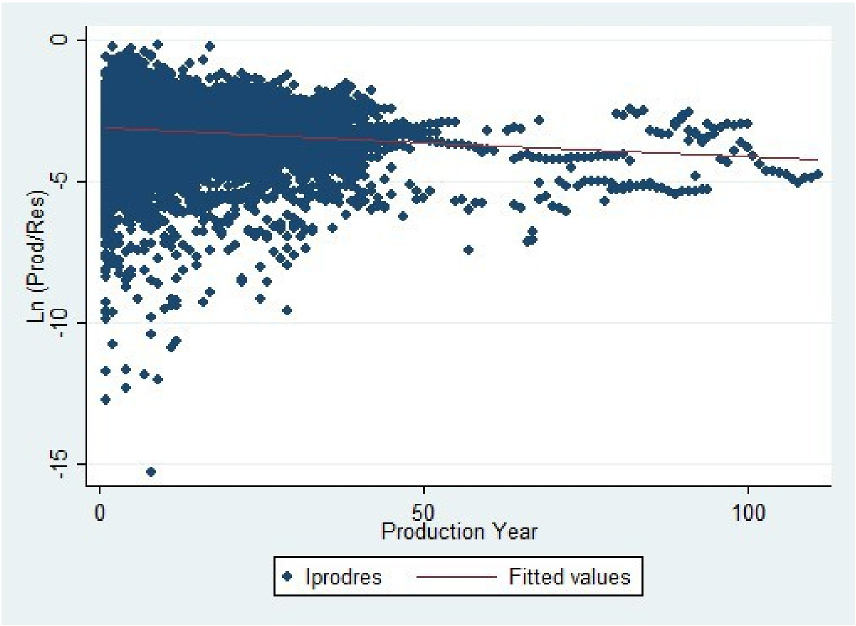

Figure C.2 Scatter plot extraction rate vs year in production for all fields

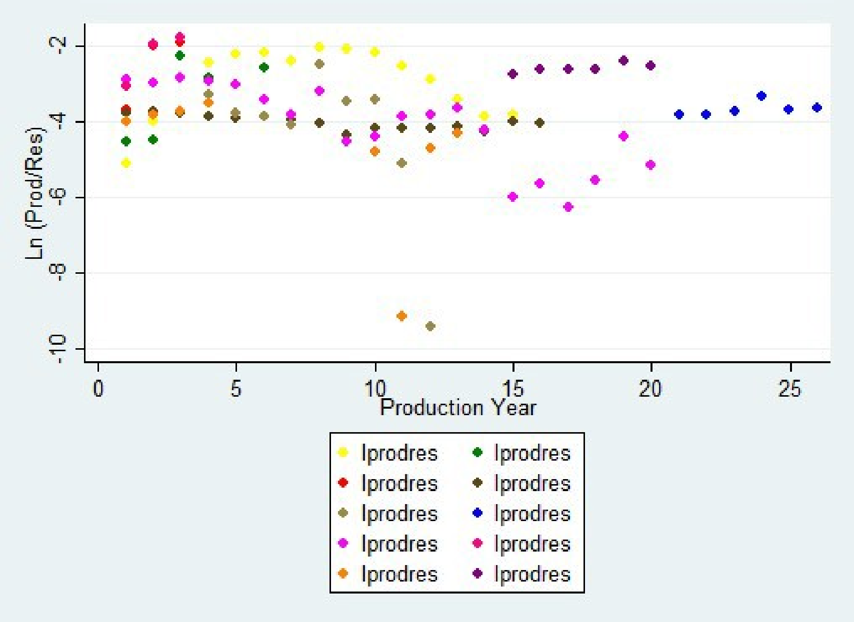

Figure C.3 Scatter plot extraction rate vs year in production for 10 random fields

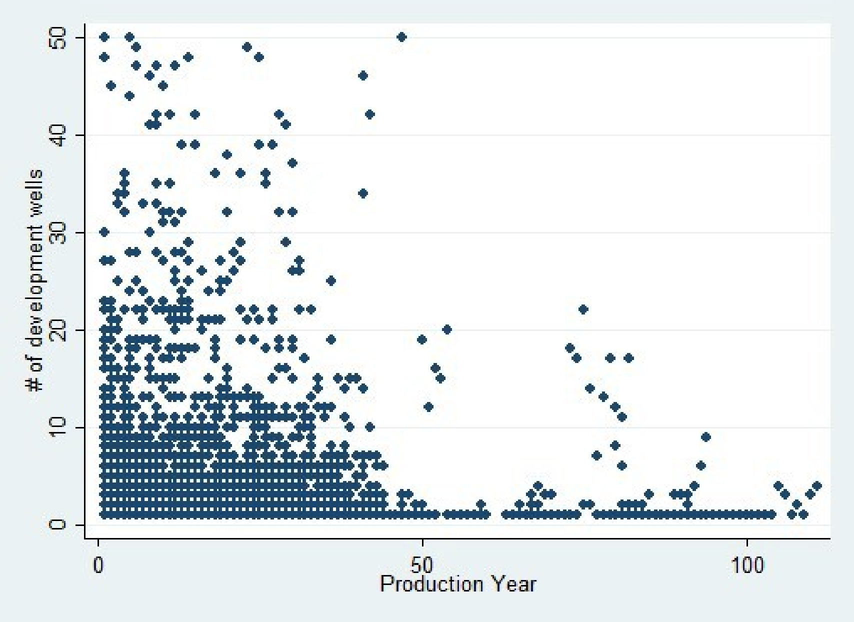

Figure C.4 Scatter plot number of development drilling vs year in production