I'll pay you later: Relational Contracts in the Oil Industry

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Abstract

International contracts are difficult to enforce, in particular in the presence of weak institutions. Resource rich economies can hold-up multinational oil companies by renegotiating tax payments after investments occurred. Anticipating such events, firms can avoid such hold-ups by devising self-enforcing agreements and relying on future gains from trade. Theoretically, this can be achieved by back-loading investments, production and tax flows. Using the universe of contracts between resource rich economies and the seven largest multinationals (Big Oil) since 1950, we show that contracts between the multinationals and resource rich economies with weak institutions are back-loaded relative to countries with strong institutions. This pattern is robust to a variety of definitions, choices of sub-samples and a large number of controls. By exploiting the timing of the first oil price shock, we show that the back-loading in countries with weak institutions only emerges in the data in early 1970s, while we do not find any evidence for back-loading between 1950 and 1970. We attribute this to binding political constraints which would not allow the US to use its military power to enforce contracts since the early 1970s and which became public knowledge during the events surrounding the Yom Kippur War in 1973.

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JEL Classification: D86, L14, H20, D02, P48, Q30.

1 Introduction

Formal institutions set rules and restrictions such as constitutions and laws that limit the discretion of individuals - and the state, - to manipulate outcomes to their advantage. Strong institutions are crucial for economic development. Indeed, previous work has established a positive cross-country correlation between various measures of economic performance and the quality of institutions (La Porta et al., 1999; Rodrik, 2000; Acemoglu, Johnson and Robinson, 2005).

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There is consensus that well-functioning institutions at least should protect property rights and enforce private contracts (Friedman, 1962). Unfortunately, many countries have to endure the presence of weak formal institutions. Consider, for instance, an oil rich country with weak institutions. Its government, to attract investment, promises advantageous tax conditions. However, once the private oil firm has invested in the country, the government is tempted to renege on its promises. Weak courts cannot prevent the government from renegotiating the contract or, in the limit, expropriating the firm. Given the government's credibility's problem, why do we nonetheless observe private investment in countries with a weak rule of law?

If the government was a firm, informal institutions could emerge to substitute for the lack of the formal ones. In particular, firms can enter into self-enforcing agreements with other firms or their employees. These ongoing informal agreements are sustained by the future value of the relationship instead of a court (Malcomson, 2013). Future rents are used to deter short-term opportunism. A growing body of empirical evidence documents these trust-based long-term relationships between private parties (McMillan and Woodruff, 1999; Antràs and Foley, 2015; Macchiavello and Morjaria, 2015; Gil and Zanarone, 2017). But, can such informal institutions emerge when one of the parties is the government itself?

To answer these questions, we turn to the oil & gas industry. It is a great setting because: (1) it is *the* capital intensive industry - for example, the US oil and gas companies invest around 3.2 million US$ per worker in their operations overseas, the next industry in line being utilities with 0.75 million US$ per worker (Ross, 2012), (2) government-firm agreements last over a large number of years and, (3) oil rich countries vary greatly in terms of the quality of their institutions. Indeed, weak institutions in general and poor property rights in particular, have been shown to slow down the use of resources and, thus, reduce the potential for countries to exploit the natural resources (Bohn and Deacon, 2000; Cust and Harding, 2020).

First, we present a model of a repeated relationship between the government and the oil & gas firm. We use a stylized version of Thomas and Worrall (1994) where we explicitly model the quality of institutions to derive our main predictions[1]. Every period, the firm invests and pays taxes to the government. The government can threaten to expropriate. In equilibrium, a self-enforcing agreement requires that the government's short-term incentive to expropriate is less valuable than the long-term gains of having the firm invest in the future. The government's inability to pay subsidies in advance (akin to a limited liability constraint), determines the dynamic investment and taxation paths. In particular, the government should be given an increasing continuation payoff, so that the firm's threat to leave the country following an expropriation is more effective. As a result, the contract is backloaded with the investment and the tax payment increasing as the relationship evolves. We show that contact backloading is more prominent the worse the quality of institutions are (modeled as the probability of enforcing the contract and hence preventing the government's expropriation). Contract backloading is a recurrent feature of dynamic contracting models without commitment and with nontransferable

[1] In Thomas and Worrall (1994), there are no formal institutions.

payoffs between parties (Ray, 2002).[2]

To test these predictions, we use a proprietary database which has been collected and provided to us by Rystad Energy.[3] Our dataset contains information on size, production, costs, revenues, taxes, fiscal regime, geology, reserves as well as a range of other characteristics for the assets (i.e. group of wells) owned or operated by the seven major oil and gas companies. Our main dataset covers assets which started production between 1970 and 1999, and we follow these assets until 2019. This amounts to 3138 country-firm-asset combinations, 127 country-firm combinations, and just above 100000 observations across 49 countries. To facilitate causal inference, we extend the dataset to cover major-operated assets with a start-up period between 1950 and 1999 (and again follow these assets until 2019). This leaves us with total of 4080 country-firm-asset combinations in 138 country-firm relations in the same countries. In our preferred specification, we classify the countries according to their quality of institutions using the level of constraints imposed on the country's executives. Measures on institutional quality in general and the level of executive constraints, in particular, are taken from Polity IV. Polity IV is a database which provides information on the quality of institutions for a large number of countries going back to the 19^{th} century.

In the empirical section, we proceed in five steps. First, we illustrate the presence of backloading in the raw data by differentiating between countries with strong and weak institutions. Second, enabled by the richness of our data set, we estimate a variety of OLS specifications to show that in countries with weak institutions, investment, production and the payment of taxes is more backloaded than in countries with strong institutions. In these specifications, we account for a large number of observables which would have the potential to confound our results such as differences in the geographic location proxied by longitude and latitude, the size of the reservoirs, climatic conditions, type of fossil fuel extracted as well as the operating company and the starting point of the relationship. Our results are robust to all of these controls.

Third, we exploit the change in the relationship between oil producing countries and firms on the global level in the early 1970s to give our estimates a causal interpretation. The change in the relationships between the multinationals and the resource rich economies provides us with a time varying intensity of the commitment problem in countries with weak institutions, using countries with strong institutions as a control. In particular, oil firms had traditionally been backed by the military power of their respective governments. Maybe the most famous example is the coup d'etat backed by the CIA in Iran following Iranian's attempt to renegotiate the fiscal regime with Anglo Persian Oil Company (nowadays BP) in 1953.[4] This started to change slowly with the creation of OPEC in 1960 which created a platform for oil rich economies to stand up to the multinationals. However the situation changed towards the end of the 1960s

[2] See Lazear (1981), Harris and Holmstrom (1982) and Fong and Li (2017) for a labor setting, Albuquerque and Hopenhayn (2000) and Fuchs, Green and Levine (n.d.) for a credit setting and Thomas and Worrall (1994) for an investment setting.

[3] Rystad Energy is a leading consultancy in the energy and mining industries. See https://www.rystadenergy.com/

[4] See 1956 Suez crisis for an example.

when the public opinion support in the US for foreign military intervention dropped due to the Vietnam war. This is best summarized by Yergin (2011):

"The postwar petroleum order in the Middle East had been developed and sustained under American-British ascendancy. By the latter half of the 1960s, the power of both nations was in political recession, and that meant the political basis for the petroleum order was also weakening. [...] For some in the developing world [...] the lessons of Vietnam were [...] that the dangers and costs of challenging the United States were less than they had been in the past, certainly nowhere near as high as they had been for Mossadegh, [the Iranian politician challenging UK and US before the coup d'etat in 1953], while the gains could be considerable."

Initially, the threat of military intervention was used to enforce the contracts and prevent oil rich countries from renegotiating or expropriating. In terms of the model, the use of a military response can act as a substitute for better local institutions and removes the need for contracts to be backloaded. Once this threat disappears, contracts need to be self-enforced and are therefore backloaded. We use this global change in the US policy which became clear to everyone in early 1970s and culminated in October 1973 with the Yom Kippur War. OPEC countries cut oil supply to the US and other OECD countries that supported Israel without triggering a military response. Responding to the new rules of the game and adjusting to the new world order, the multinationals quickly adjusted and started backloading production, tax payments and eventually investments.

Fourth, after establishing the causal relationship between the firms inability to enforce a contract and the backloading of contracts, we test a key theoretical prediction of the model by moving the analysis to the relationship level between a firm and a country. We define the start of the relationship to be either the year in which a firm is awarded an extractive license for the first time or 1970 in case the firm entered before that year. The latter is motivated by the above discussed resetting of any previously existing relationship. Using the start of the relationship date to infer relationship duration, we show that backloading vanishes after approximately 30 years of the relationship.

Finally, we provide heterogeneity analysis and test robustness of our results. In particular, we show how the backloading in weak institutional environment is observed across on-shore assets, but not across off-shore ones. We argue that this finding is due to the technical difficulty of exploiting the latter ones, making them less of a target for state expropriation.

The findings of this paper contribute to three large. To the best of our knowledge, we are the first to provide empirical evidence about contract back-loading predicted by a large body of theoretical literature on dynamic contracting with limited commitment (Ray, 2002). Thus, we contribute to the empirical literature on self-enforcing contracts (Antràs and Foley (2015), Macchiavello and Morjaria (2015), Gibbons and Henderson (2013) and Blader et al.

(2015)).[5] The progress of this literature has been limited by the unavailability of transaction data in environments with limited or no formal contract enforcement and it has focused on inter and intra-firm relationships. Instead, in our paper, one contracting party is the government allowing us to explore whether public entities can also establish these informal relationships. Therefore, the second literature we contribute to is the one on political economy. We are the first to show that the government can backload taxes as way to overcome the lack of institutions.

Finally, in the resource economics literature, other papers have looked at the effect of institutions in the oil industry. Stroebel and Van Benthem (2013) consider a model where the oil company can provide the government with insurance. They consider stationary contracts and show that expropriation occurs in equilibrium (unlike in Thomas and Worrall (1994)) because the government's expropriation cost is private information. Empirically, they find that expropriation is more likely when oil prices are high and that oil companies offer more insurance to countries with better institutions. Guriev, Kolotilin and Sonin (2011) also find empirically that nationalization is more likely to occur when oil prices are high and the quality of institutions low, but they use a model where firms (not the governments) can renege on the taxes. Thus, taxes cannot be too high to ensure that they are paid, such that, as a result the government has incentives to expropriate when oil prices are high. Finally, Jaakkola, Spiro and Van Benthem (2019) show that taxation and investment exhibit cycles by using a model where the government's commitment is limited to one period and the company cannot commit to never invest in the future. We are the first to document empirically the consequences of lack of commitment on the timing of investment and tax collection.

In the next section we set up a model and derive the hypotheses. In section 3 we describe the data and the stylized facts. In section 4 we present the results. In the last section we conclude.

2 The model

Following Thomas and Worrall (1994), we present a stylized model of the relationship between a government (he) and an oil and gas firm (she). In order to derive empirical predictions, we explicitly model the quality of institutions that limit the extent to which governments can expropriate the firm.

The government and the firm interact repeatedly over an infinite horizon of periods. The timeline for each period is shown in Figure 1. Every period, the government and the firm agree on a non-contractible investment and a transfer. Then, the firm provides an investment I_t (which depreciates within one period[6]). An oil price p_t is then realized which, together with the investment, determines the firm's profit $r(I_t; p_t)$. The price p_t is *i.i.d.* over time and, for simplicity, we consider two equi-probable states: $p = 0$ (low oil price) and $p = 1$ (high oil price).

[5] See Gil and Zanarone (2017) for a recent survey.

[6] Thomas and Worrall (1994) show that the results are not qualitatively affected by capital accumulation, which is clearly the case in the oil and gas industry.

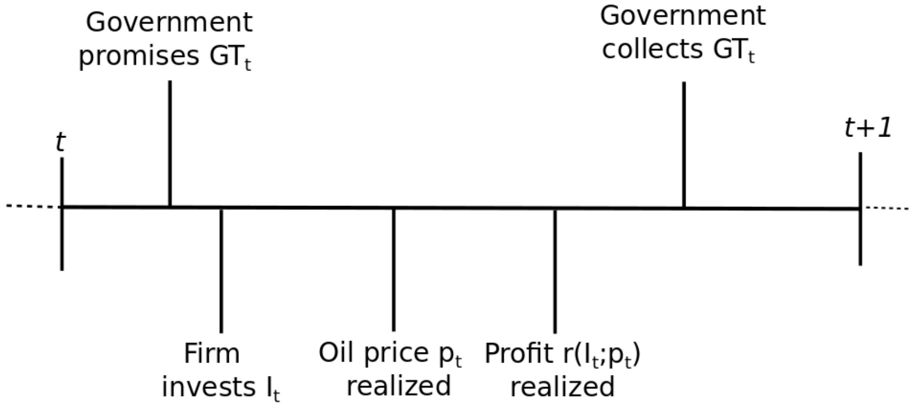


Figure 1: Timeline of period t

To simplify the exposition of the model, we assume that $r(I_t; p_t) = p_t 4\sqrt{I_t}$. Hence, when the oil price is low, there are no revenues to be expropriated. Finally, the government chooses a transfer GT_t (i.e. overall government take), leaving the firm a net profit of $r(I_t; p_t) - GT_t$. The government and the firm have the same discount factor δ and are credit-constrained: $r(I_t; p_t) - GT_t \geq 0$ and $GT_t \geq 0$. Regarding the information structure, everything is observable to everyone.

An agreement A at time t is a pair (I_t, GT_t) that depends on the history up to time $t-1$. Following Thomas and Worrall (1994), we define the optimal contract as the one that maximizes the firm's payoff at the beginning of the game. The expected per-period payoff functions of the government and the firm can be written respectively as follows:

$$V_t = (1-\delta)\mathbb{E}\left[GT_t\right] + \delta\mathbb{E}\left[V_{t+1}\right]$$
$$U_t = (1-\delta)[-I_t + \mathbb{E}\left[r(I_t; p_t) - GT_t\right]] + \delta\mathbb{E}\left[U_{t+1}\right]$$

The extent to which the agreement A can be legally enforced depends on the quality of the courts $C \in [0, 1]$. When $C = 1$, the agreement can be perfectly enforced by the courts, while if $C = 0$, the courts are completely ineffective and the agreement needs to be self-enforced. This means that neither the government nor the firm should ever have an incentive to violate it ex-post.

If the government deviates from the agreed transfer, it is assumed that the firm will never again invest in the country. Therefore, if the government deviates, he appropriates as much profits as the quality of courts permits. The following self-enforcing condition ensures that, for a given p_t, the government has incentives to honor the agreement at time t:

$$GT_t + \delta V_{t+1} \geq GT_t + (1-C)[r(I_t; p_t) - GT_t] \qquad \text{(SE)}$$

This constraint says that, for the government to honor the agreement, the discounted future value of the relationship δV_{t+1} (in terms of future taxes and investment) should be larger than what the government is allowed to expropriate in the current period. Note that with the strongest possible rule of law ($C = 1$) this constraint is always slack, while in the absence of courts ($C = 0$), the model is equivalent to that of Thomas and Worrall (1994).

Define I^* as the profit maximizing level of investment: $E\left[r'(I^*; p_t)\right] = 1$, that is, $I^* = 1$. Whenever the quality of institutions is high enough such that the self-enforcing constraint (SE) is slack, the firm invests I^* every period. The transfers will determine how the government and the firm share the surplus but will not affect the level of investment. For instance, the contract that maximizes the firm's payoff will have no transfers so the the government gets his outside option of zero. Any path with positive transfers (that satisfy the firm's participation constraint) is also possible.

Whenever institutions are weak enough such that condition (SE) binds, Thomas and Worrall (1994) find that the optimal self-enforcing agreement A is "back-loaded". In other words, the government's value from the relationship increases over time. The firm achieves this: first, by progressively increasing investment until the first best level I^* is achieved,[7] and second, by increasing the taxes paid to the government.[8] We reproduce here Proposition 1 from Thomas and Worrall (1994) and prove it in the Appendix for the stylized model where the quality of institutions is allowed to vary.

Proposition 1. *When the self-enforcing constraint (SE) binds, investment is non-decreasing over time, attaining a maximum value in the steady state with probability one which may be less than the efficient level. The discounted utility of the government is also non-decreasing and transfers are zero until the period before the maximum value of investment is attained.*

The rationale behind this contract is that, the firm, by delaying the payment of taxes and the investment, makes the threat of terminating the relationship more effective by increasing the government's cost of deviation. In other words, a back-loaded agreement enhances the government's credibility by pushing potential gains towards later parts of the relationship.

Figure 2 depicts the firm's value $U(V)$ as a function of the value given to the government, V, in countries with three different quality of institutions: $C \in \{1, 0.8, 0\}$. When $C = 1$, $U(V)$ corresponds to the efficient frontier in black, where any point can be sustained as a stationary contract. Note that the point that maximizes the firm's utility will give the government $V = 0$. However, if the government has a better outside option (as it is typically the case in countries with strong institutions), the firm will need to at least give this value. When $C = 0.8$ or $C = 0$, the constraint (SE) binds and the efficient frontier cannot be fully achieved. As a result, the contract is backloaded.

[7] If the discount factor is small enough, the efficient level of investment will never be reached, see the Appendix.

[8] The authors show that if the government is risk averse or there is capital accumulation (i.e. I_t does not fully depreciate within each period), the government take can be paid earlier on but the dynamic backloaded structure of the contract will remain unchanged.

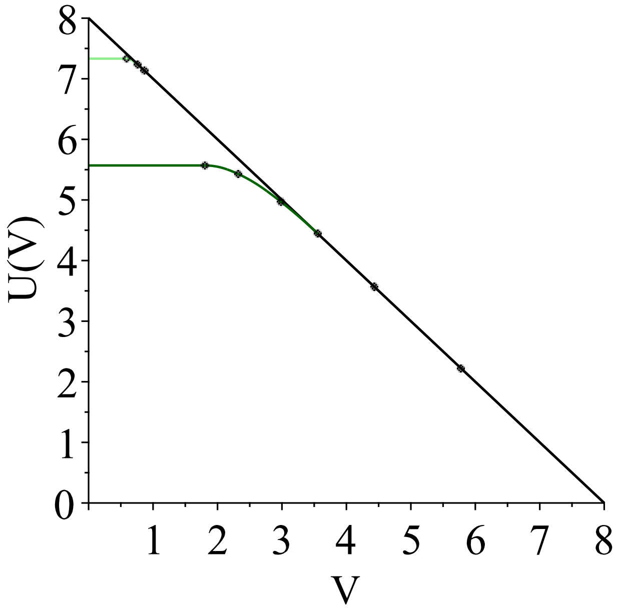


Figure 2: Value function when $\delta = 7/8$ and $C \in \{1, 0.8, 0\}$

The dots on the frontier of Figure 2 represent the path of government value over time following the realization of a high oil price.[9] Note that when $C = 0.8$, the efficient frontier (where the contract becomes stationary) is achieved faster than when $C = 0$. As a result, there is less need to delay the giving utility to the government. The following Proposition summarizes this comparative statics result.

Proposition 2. *The agreement A is more backloaded the weaker the courts are.*

The delay in giving value to the government is achieved by delaying investment and the payment of the government take. Figure 3 depicts the optimal investment and government take over time (i.e. periods where price is high) for $C = 0.8$ and $C = 0$. In a setting with strong courts (i.e. $C = 0.8$), investment starts being larger and achieves the first best level ($I^* = 1$) earlier than with weak courts (i.e. $C = 0$). Similarly, the payment of government take starts earlier when courts are strong.

An alternative way to visualize the result in Proposition 2 is to plot the cumulative shares over a fixed number periods (with a high oil price). This allows us to see that a given cumulative share of investment or government take is reached faster in countries with strong courts as compared to countries with weak courts. In Figure 4, we depict the cumulative share of investment, government take and production over time for different $C \in \{0.8, 0\}$. The horizontal dashed line marks the 66% of the cumulative share while the vertical dashed lines indicate how many periods with high oil price it takes to reach this level.

[9] When the oil price is low, there are no revenues to expropriate and the firm should not increase the government's value to eliminate the temptation to expropriate. More precisely, the government's value stays the same $V_t = V_{t=1}$ following $p = 0$.

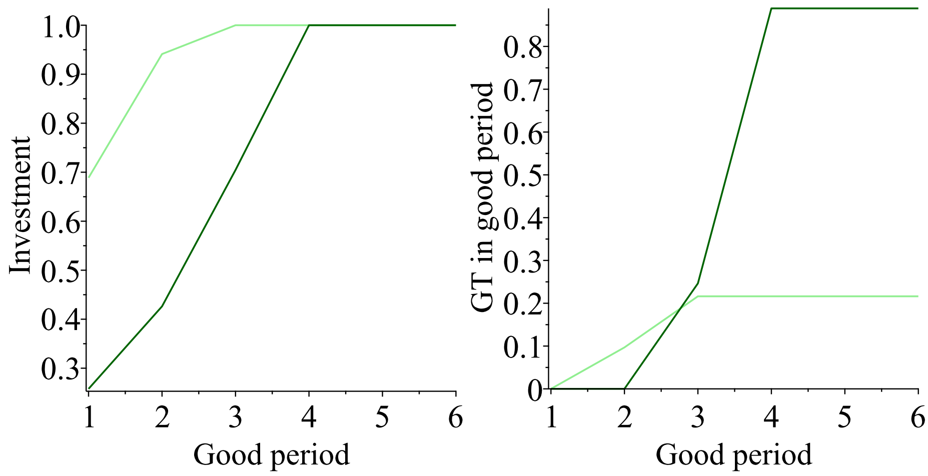


Figure 3: Optimal agreement over periods with a high price when $\delta = 7/8$ and $C = 0.8$ & $C = 0$

In the empirical section, we test the hypothesis derived by Proposition 2.

Hypothesis. The government's take and the firm's investment are back-loaded in countries with weak institutions compared to those with strong institutions.

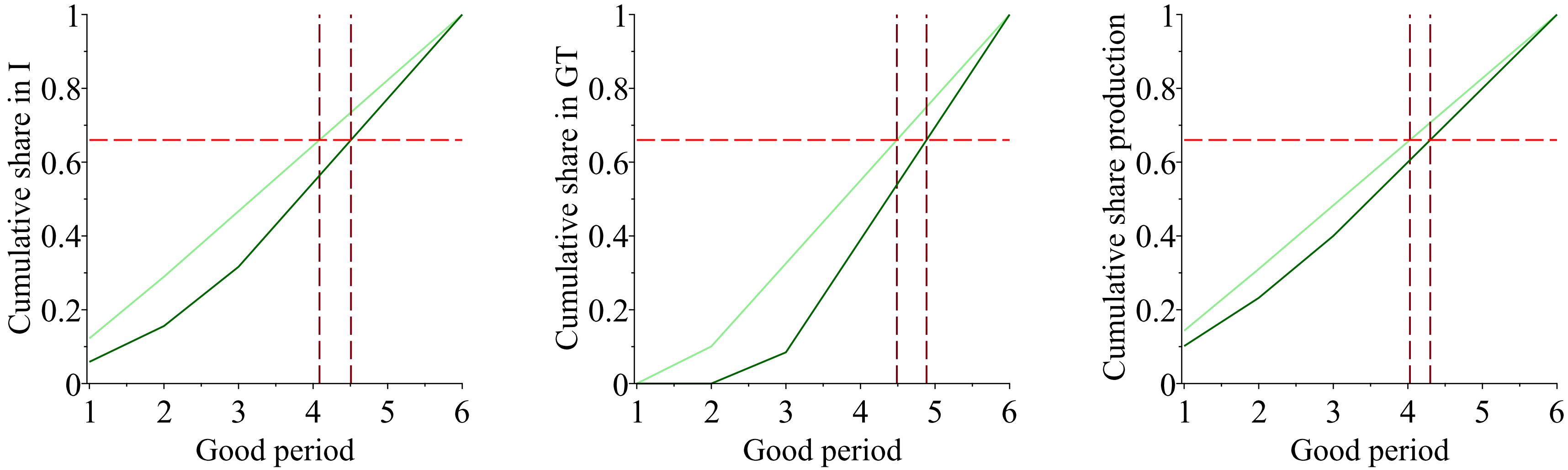


Figure 4: Cumulative shares over periods with a high price when $\delta = 7/8$ and $C = 0.8$ and $C = 0$

3 Data and Empirical Facts

Oil and gas data The oil and gas data using in the paper comes from Rystad Energy, an energy consulting firm based in Norway. Its U-Cube database contains current and historical data on production, ownership, costs, geology, reserves as well as a range of other characteristics for all oil and gas assets across the world. Rystad collects its date from a wide range of sources, including oil and gas company reports, government reports, interviews with company representatives, etc. In some cases, when the detailed data disaggregation is not available, Rystad imputes asset-level production and costs by using sofisticated engineering modelling (see Asker et all. (2018) for the detailed description of data collection process). Rystad data is, arguably, one of the best existing data sources abouit oil and gas industry.

We collect information for assets operated by seven largest publicly traded oil and gas companies, so-called oil majors: BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Royal Dutch Shell and Total. Our main dataset contains all assets that started producing after 1969 and were operated by one of supermajors. As our central research question concerns backloading in the relational contracts between firms and governments, and that would need time to develop, we require the assets to be present in the database for at least 20 years. This implies that our dataset includes all ever producing major-operated assets with the production start between 1970 and 1999. The data for the asset operations potentially continues till 2019.

The dataset used for causal inference extends the above data to major-operated assets with the production start between 1950 and 1999. Again, we follow these assets' operations till (at most) 2019.

For each of the assets above we observe years of award and start of production, yearly data on fiscal regime, ownership, production, different capital costs, revenue, profits, government's take, reserves, climate, type of commodity, geological characteristics, off- vs. on-short type of production, as well as geographical location. Below we provide more details about the data, as well as descriptive statistics.

Award and start of production years. The years when the exploration license was granted, and when the asset started production, respectively. Typically, award will be followed by the discovery, and then by production.

Fiscal regime. For each asset, a contract between a firm and a country can take a form of production sharing agreement (PSA) , tax/royalty contract (or concession) and a service agreement. If the firm is granted 100% ownership of the product extracted, the agreement is referred to as a concession. The agreement is referred to as a service contract if the firm is granted 0% ownership and as a production sharing agreement if the firm is granted between 0 and 100% ownership. Such agreements imply that at least a share of the generated revenues by the firm is owned by the government of the country in which the firm is operating. The negotiation and the shares allocated vary greatly and depend on a country's petroleum laws and regulations.

The total amount and the structure of payments received by the government under one of the agreement are typically referred to as a fiscal regime. In some countries, a single fiscal regime applies to the entire country; in others, a variety of fiscal regimes exist. In many cases, the agreements allocated to the same firm within the same country are also interlinked in a variety of ways, such as a joint calculation of the tax base.[10]

Ownership. We only use asset-level data during the period when they were operated/owned by one of the majors. For almost all of our assets a major is also the company that started the production (that is, a transfer of ownership from a supermajor to a non-major company, if any, has happend in the later years of assets' existence). We exclude the assets where the discovery, and the first years of production were not done by a supermajor.

Production, Revenue and Profits. For each asset we observe yearly production, revenue and profits data by type of hydrocarbon (e.g., oil, gas, etc.). Production is given in thousands of barrels for liquids, barrels of oil equivalent for gas per day. Profit and revenue are originally given in millions current USD. To make them comparable across time, we discount them using the US CPI to obtain values in real 2018 USD. (If the asset is jointly operated by several companies, we observe their levels of production, revenues and profits from this asset separately based on production sharing agreement.) We exclude assets with negative profits from our sample, as in absence of profit does not allow measuring allocation of surplus between government and the firm.

Investment/Capital costs. In our analysis we mostly rely on two measures of investment - well capital expenditures and facility capital expenditures. The former is defined as capitalized costs related to well construction, including drilling costs, rig lease, well completion, well stimulation, steel costs and materials, and the latter as costs to develop, install, maintain and modify surface installations and infrastructure. Both are denominated in millions of real 2018 US dollars.

Government's take. The government's take captures the total amount of payments received by the government. It is the the most common statistic used for the evaluation of contracts (Johnston, 2007; Venables, 2016). See Johnston (2007) for a discussion of the advantages and the disadvantages of such a measure. See Mintz and Chen (2012) for an excellent survey of tax and royalty systems across a number of countries for which detailed data is publicly available.
In our analysis, it is defined as all cash flows destined to the authorities and land owners, including royalties, government profit oil (PSA equivalent to petroleum taxes), export duties, bonuses, income taxes and all other taxes and fees. It is measured in millions of real 2018 dollars.

[10]See the Global Oil and Gas Tax Guide 2017 for examples. Available at: http://www.ey.com/gl/en/services/tax/tax-services_access-our-global-tax-guides

Reserves Reserves are defined in the data as the remaining economically recoverable volumes. In our analysis we use reserves at the beginning of asset' production as a proxy for asset size.

Institutions To test our hypothesis, we need data that differentiates between countries with weak and strong institutions. We use several versions of such data. First, we employ Polity IV dataset, which has measures containing annual information on regime and authority characteristics for a large number of countries. We classify countries into those with strong vs. weak institutions based on the executive constraints (XCONST) variable, which measures the extent of institutional constraints on the decision-making powers of the chief executive, whether an individual or a collective executive. To avoid the reverse causality issues from the oil wealth to institutions, we set out classification on the XCONST data in ten year prior to the beginning of our sample. Our alternative definition bases the definition of a strong institutions country on OECD membership. As a robustness check, we also define weak institutions countries as those who were part of OPEC prior to our consideration period.

Tables 1 and 2 provide the summary statistics at the asset level for the baseline sample and the extended sample for the causal inference analysis, respectively, for the entire sample and the split between countries with strong and weak institutions. We see that there are only marginally more assets in strong-institutions countries in comparison to the weak-institutions ones. Oil-producing assets are overrepresented in countries with weak institutions, while gas-producing - in strong ones. Average timing of award and start of production do not differ much across regimes, and neither does average duration of production. Strong countries are operating relatively larger assets, which are associated with relatively lower revenues. Our main variable of interest, Government Take, constitutes roughly 43 percent of revenues across the sample. In weak instiution countries this proportion is around 50 percent, while in strong ones only 38 percent of revenues goes to the government on average.

Table 1: Descriptive statistics: Baseline sample (Start-up years 1970-1999)

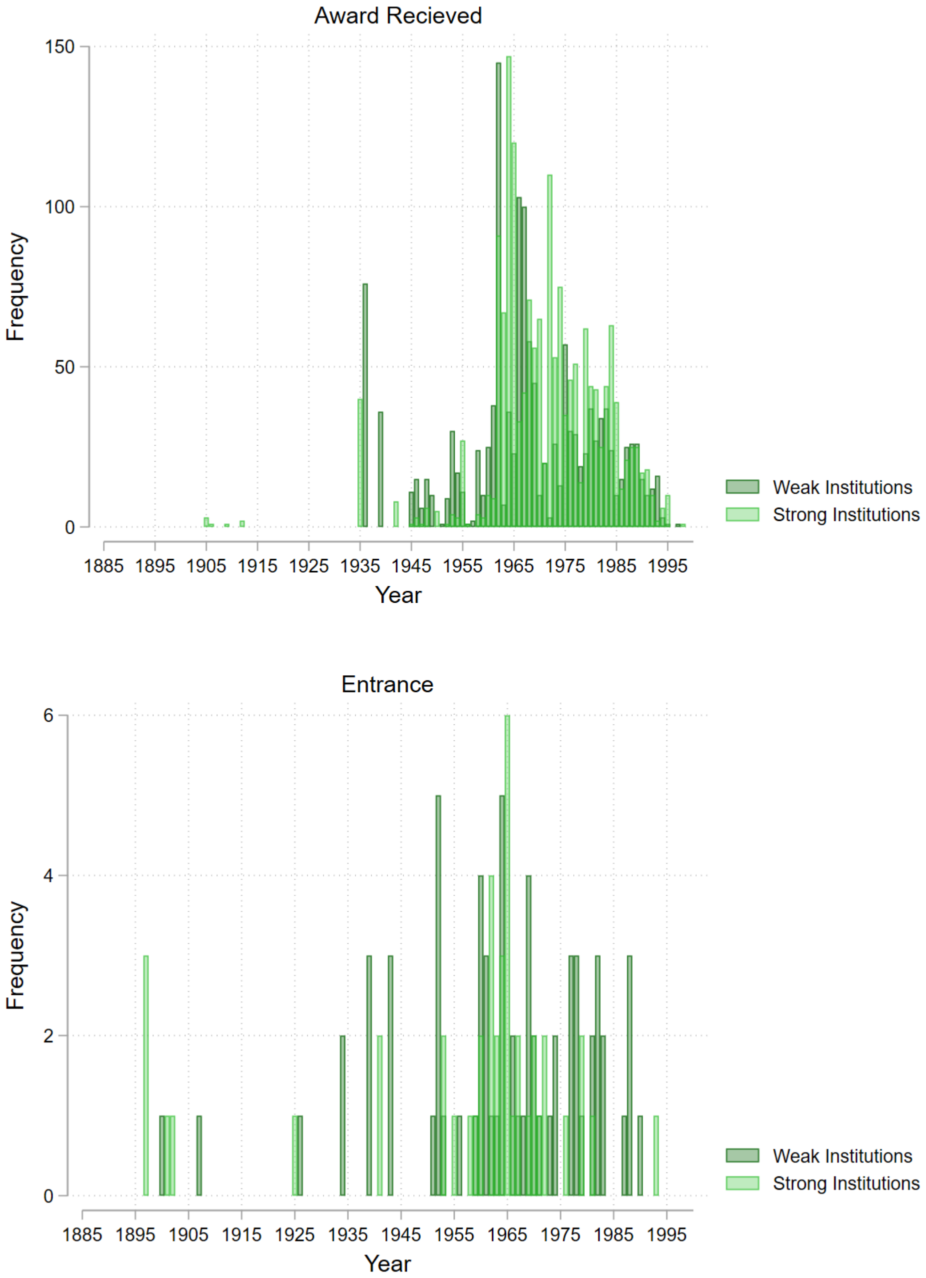
	All countries			Countries with strong institutions			Countries with weak institutions		
	mean	sd	N of assets	mean	sd	N of assets	mean	sd	N of assets
Award Year	1969	13.0	3138	1971	11.7	1696	1968	14.1	1401
Startup Year	1986	8.8	3138	1987	8.6	1696	1984	8.8	1401
Duration of production, years	31	8.5	3138	30	8.2	1696	32	8.6	1401
Cumulative Production Kbbl/day	108.3	436.5	3138	107.0	527.0	1696	109.7	298.9	1401
Reserves at production start, Mln bbl	49.3	196.4	3138	45.1	224.0	1696	54.4	159.5	1401
Cumulative Real Profit, MUSD	328.5	1827.5	3138	312.2	2073.7	1696	346.4	1499.9	1401
Cumulative Real Well Capex, MUSD	202.8	731.3	1860	290.7	995.9	783	137.9	442.5	1059
Cumulative Real Facility Capex, MUSD	145.4	528.5	3127	162.9	645.7	1689	126.8	346.4	1397
Cumulative Real Exploration Capex, MUSD	49.9	153.8	1749	86.5	227.0	722	24.0	50.0	1012
Cumulative Real Total Cost, MUSD	606.4	2885.0	3138	728.1	3757.5	1696	466.3	1227.1	1401
Cumulative Real Subsidies, MUSD	46.1	151.4	2651	54.4	179.3	1675	31.3	83.6	935
Cumulative Real Government Take, MUSD	846.8	3989.4	3138	657.8	4425.4	1696	1079.7	3430.3	1401
Cumulative Real Revenue, MUSD	1782.2	8325.2	3138	1698.8	10030.5	1696	1892.7	5758.2	1401
Government Take to Revenue ratio	0.4	0.2	3138	0.4	0.1	1696	0.5	0.2	1401
Fiscal Regime									
Production Sharing Agreement			589			2			587
Royalty/Tax			2535			1694			800
Service Agreement			14			0			14
Off- vs. Onshore									
Offshore Assets			1830			1300			493
Onshore Assets			1308			396			908
Commodity type									
Oil and other liquids			1258			306			942
Gas, condensate and NGL			1880			1390			459

Table 2: Descriptive statistics, Causal inference sample (Start-up years 1950-1999)

	All countries			Countries with strong institutions			Countries with weak institutions		
	mean	sd	N of assets	mean	sd	N of assets	mean	sd	N of assets
Award Year	1965	14.9	4080	1965	15.3	2365	1965	14.2	1671
Startup Year	1980	13.3	4080	1979	14.7	2365	1981	11.0	1671
Duration of production, years	36	12.5	4080	37	13.6	2365	35	10.8	1671
Cumulative Production Kbbl/day	124.0	541.6	4080	110.0	565.5	2365	142.7	510.3	1671
Reserves at production start, Mln bbl	56.1	234.6	4080	45.5	229.9	2365	70.7	242.5	1671
Cumulative Real Profit, MUSD	375.6	1959.4	4080	327.0	2049.4	2365	439.5	1837.6	1671
Cumulative Real Well Capex, MUSD	208.6	707.0	2364	253.9	868.2	1092	168.2	530.6	1251
Cumulative Real Facility Capex, MUSD	142.1	513.5	3919	143.2	582.4	2211	142.1	412.1	1664
Cumulative Real Exploration Capex, MUSD	48.7	146.3	2202	79.9	207.6	992	23.0	46.8	1193
Cumulative Real Total Cost, MUSD	613.2	2807.1	4080	649.8	3304.1	2365	563.5	1939.7	1671
Cumulative Real Subsidies, MUSD	44.4	143.9	3540	48.5	163.3	2331	35.8	96.0	1165
Cumulative Real Government Take, MUSD	954.2	4845.3	4080	621.2	4228.9	2365	1423.5	5612.6	1671
Cumulative Real Revenue, MUSD	1944.0	9089.5	4080	1599.5	9306.7	2365	2426.8	8844.2	1671
Government Take to Revenue ratio	0.4	0.2	4080	0.4	0.1	2365	0.5	0.2	1671

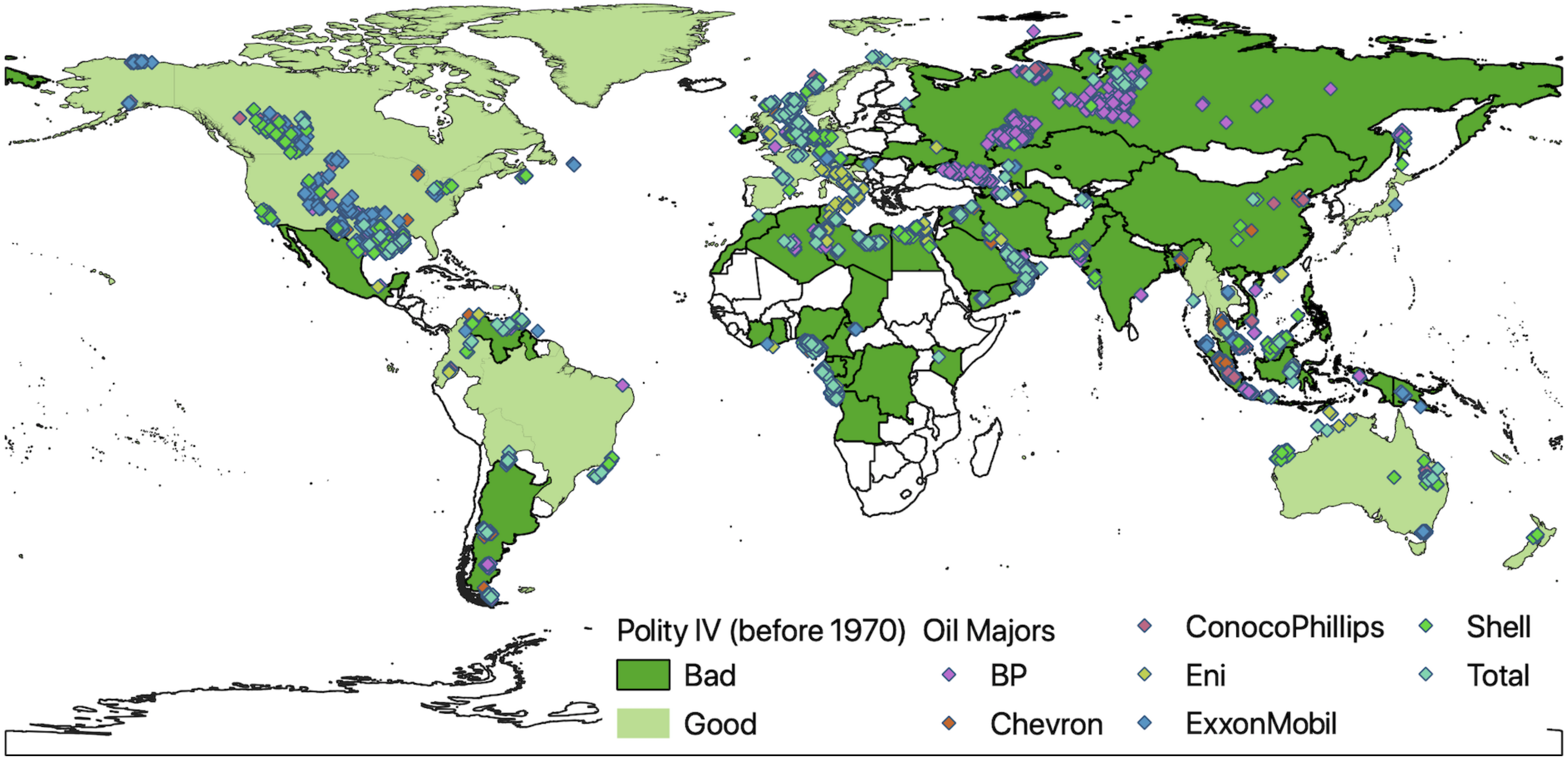
In Figure 5 and Figure 6 we observe the spatial and the time variation of assets. An asset may be thought of containing at least one production well and be operated by at least one firm with the initial property right being owned by at least one country. In Figure 5 we provide information on the number of relationships starting between a particular firm and a particular country as well as the total number of awards received by the firms in our sample throughout the 20th century.

Figure 5: Awards and Entrance



Source: Rystad data on investment

Figure 6: Firms' Assets and Quality of Institutions



Source: Rystad and Polity IV

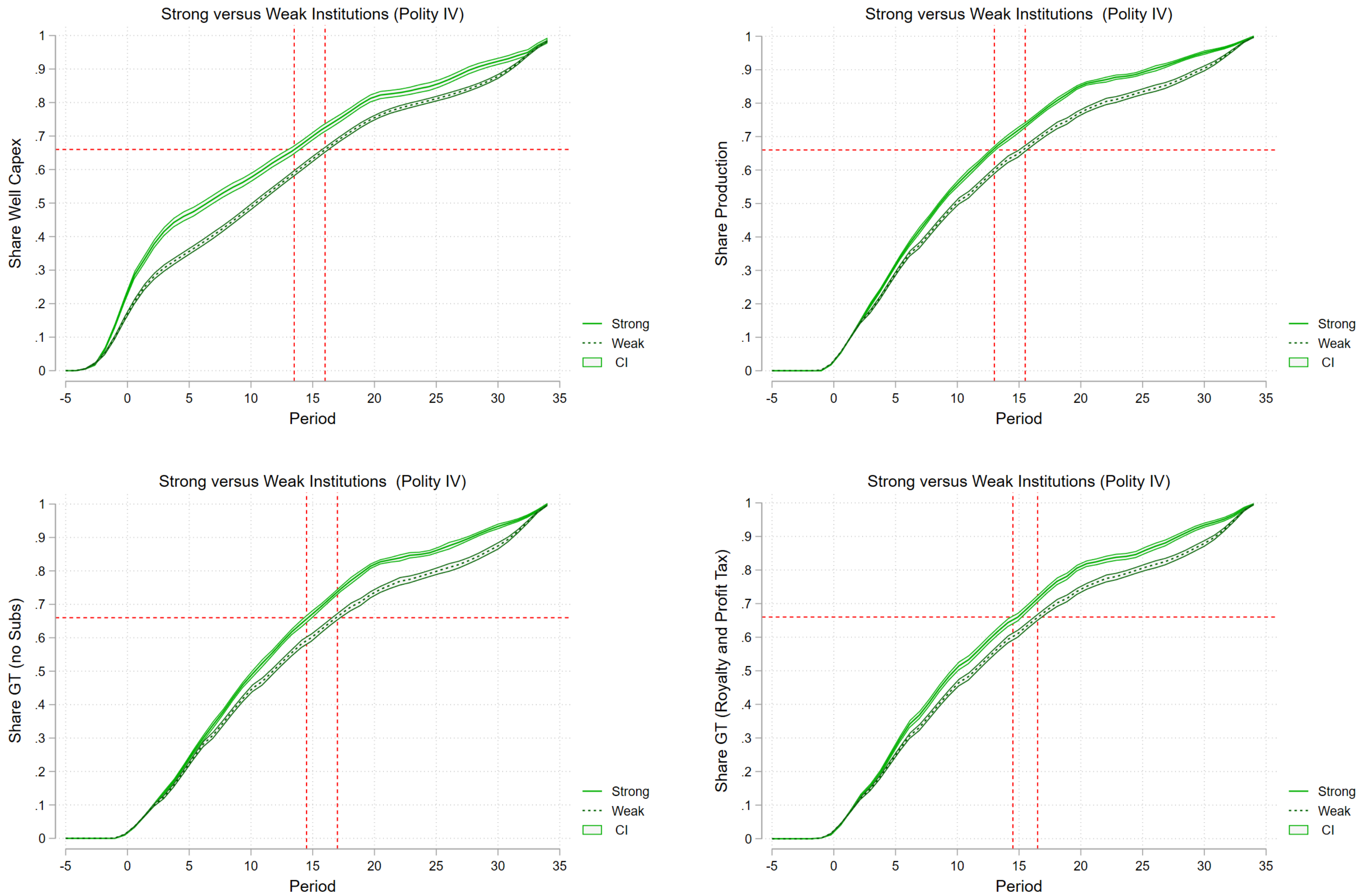
3.1 Empirical facts

In this section, we use raw data at the asset level to illustrate the presence of agreement backloading in four key variables: well CAPEX, production and two measures of government take (overall government take and royalty & profit tax only). An asset may be thought of containing at least one production well and be operated by at least one firm with the initial property right being owned by at least one country. The measure that we use to capture the delay in the different measures consist in the number of years that are needed to reach 66% of the cumulative measure over a particular period of time. To this end, we construct the following variable $y_{aj} = \frac{\sum_{p=-1}^{j} \delta^p X_p}{\sum_{p=-5}^{P} \delta^p X_p}$ with asset a and period p of asset relationship and $P \in \{30, 35, 40\}$ being the upper bound of the period until which X is added up. Thus, in period 0, and in period X the values on the Y-axis should be 0 and 1 respectively and identical for countries with strong and weak institutions. However, between these periods the "first order stochastic dominance" of the average CDF in countries with strong institutions would be consistent with the presence of backloading in countries with weak institutions.

The four different measures for backloading with $X = 35$ can be found in Figure 7.[11] We observe that in order to reach 66% of the cumulative measure over the 35 year period, it will take the firm 1-3 years more in countries with weak institutions relative to countries with strong institutions. All measures in Figure 7 are consistent with our hypothesis and imply that firms backload investment, production and tax payment in countries with weak relative to countries with strong institutions. Two remarks are in order. First, for the production variable, we do not need a discount factor such that $\delta = 1$. Thus, the empirical facts are insensitive to the choice of the discount factor. Second, in the next section the number of years which are necessary to reach a certain threshold is our main outcome variable.

[11] Our results are not sensitive to the specific threshold of 66%.

Figure 7: Within Asset up to 35 years (Polity IV)



Source: Rystad data on investment

4 Identification and Results

4.1 Backloaded contracts at the asset level

As mentioned in the previous section, we measure the degree of backloading as the number of years for every asset which it takes to reach k % of the cumulative flows with $k \in \{50\%, 66\%, 75\%\}$ as indicated by the vertical lines in Figure 7. Our results are not sensitive to the choice of this threshold and thus we proceed by focusing on the 66% threshold. Thanks to the richness of our dataset, we can account for a large number of asset characteristics to ensure that difference in backloading are not driven by geological and geographical differences between assets located in countries with strong and weak institutions. In particular, we account for location and climatic conditions as well as the size of the reservoir and the type of fossil fuel extracted. To capture some basic relationship parameters, we also account for firm FE as well as two types of time FE. We account for the year in which production started in a particular asset and the year in which a firm stated operating in a particular country for the very first time (see Figure 5). Conditional on these observables and constant unobservables, we provide the results in Table 3. Note that while the first row in every Panel uses the Polity IV measure to differentiate between countries with strong and weak institutions, we also show that our results are not sensitive to a specific choice of this measure. In particular, we alternatively differentiate between OECD and non-OECD countries as well as non-OPEC and OPEC countries such that only OPEC countries are defined as countries with weak institutions. More formally, we estimate the following specification with a indicating an individual asset:

$$y_a = \beta \text{Weak Country}_{c(a)} + X_a' \gamma + \varepsilon_a$$

with β being the coefficient of interest, telling us the difference in the number of years between reaching 66% of production, investment as well as tax payments by differentiating between countries with strong and weak institutions. The standard errors are clustered in three dimensions: country, start-up year and firm. the results in Table 3 are robust to the inclusion of all controls and variations in the measure of our LHS as well as our main RHS variable.

4.2 Shift in the firm-government power relations

In order to push towards causality, we exploit a well documented historical event and the implied time variation which significantly changed the relationship between the resource rich economies and the firms. We briefly summarize the events in this section and provide more background information in the Appendix.

During the World Wars, it became apparent the importance of access to oil to move the troops. The US started wondering *"What would a pervasive and lasting shortage [in oil] mean for America's security and for its future?"* Yergin (2011). And the government set policies with the goal to secure access to oil: *"The State Department should work out a program to [...] promote the expansion of United States oil holdings abroad, and to protect such holdings*

TABLE 3
66% for 35 Years sample

Panel A: Investment (Well Capex)

	(1)	(2)	(3)
Weak (Polity IV)	4.695***		
	(1.290)		
Weak (OECD)		5.853***	
		(1.415)	
Weak (OPEC)			7.399***
			(1.200)
N	1801	1818	1275
R-sq	0.33	0.33	0.44

Panel B: Production

	(1)	(2)	(3)
Weak (Polity IV)	2.127**		
	(0.776)		
Weak (OECD)		2.765***	
		(0.656)	
Weak (OPEC)			3.807***
			(0.689)
N	3087	3128	2349
R-sq	0.44	0.45	0.50

Panel C: Royalty and Profit Tax

	(1)	(2)	(3)
Weak (Polity IV)	2.639**		
	(1.084)		
Weak (OECD)		3.304***	
		(1.048)	
Weak (OPEC)			4.889***
			(0.888)
N	2467	2508	1733
R-sq	0.36	0.36	0.44

Panel D: Government Take (no Sub.)

	(1)	(2)	(3)
Weak (Polity IV)	2.264**		
	(0.860)		
Weak (OECD)		2.724***	
		(0.802)	
Weak (OPEC)			4.226***
			(0.720)
N	3086	3127	2348
R-sq	0.35	0.36	0.42

Notes: Year of Start Up Fixed Effect included in all regressions. We also control for year of entrance, firm, climate and fossil fuel type FE as well as Longitude, Latitude and logged physical size of the reservoir. Left hand side variable is indicating the number of years until 66% of total level of well capex investment, production and payments after 35 years is reached. Standard errors in parenthesis clustered by country, Start Up Year and Firm. * stands for statistical significance at the 10% level, ** at the 5% level and *** at the 1% percent level.

as already exist." Yergin (2011) Hence, in the oil markets in the 1950s, the oil firms have been backed during their expansion into the rest of the world by the US and UK military. Maybe the most famous example is the CIA initiated Coup d'etat in Iran following Iranian's attempt to renegotiate the fiscal regime with Anglo Iranian Company (nowadays BP) in 1953.

In terms of the model in Section 2, the governments in countries with weak institutions were facing the following adjusted self-enforcing constraint:

$$GT_t + \delta V_{t+1} \geq GT_t + (1 - C)[r(I_t; p_t) - GT_t] - K \tag{SE'}$$

where K is the cost imposed on the country by the military intervention inflicted by the firm's original country. For any C, if K is large enough, it is easy to see that the constraint (SE') will not be binding. In other words, the military intervention acts as a substitute for a weak rule of law. For large K and small C, the agreement is enforced not by the courts but by the threat of military intervention following the government's deviation. Since the agreement is enforced, it does not need to be backloaded.

In 1960, OPEC was created to renegotiate the agreements. While initially not always successful, OPEC's attempts to change the contract terms started to pay off coinciding with an increasing dissatisfaction of the US population with the military US involvement in Vietnam **?**. It eventually ended in 1973 with a complete US withdrawal. This significantly reduced the politician's incentive to start another military intervention in the Middle East such that the initially strong military backing started fading. In 1973, this change in the US policy became common knowledge when the Arab-Israeli War unfolded. The US helped Israel and the OPEC countries responded by: *"Using oil as a weapon, the Arab producers imposed an embargo on the United States and other nations supporting Israel".* Vietor and Evans (2003). OPEC's cut of the supply of oil to the US did not trigger any military response. Thus, by 1974 it must have been apparent to everybody in the oil and gas sector that the rules of the games have changed. And while the oil companies could have relied on the US government to intervene and enforce the contracts in the past, they have now been forced to come up with alternative strategies to enforce contracts. After 1973, K is set to zero and the agreement needs to be self-enforcing and hence backloaded.

To test this hypothesis we estimate the following specification (using the same controls as above) and graphically present the estimated coefficient in Figure 8:

$$y_a = \sum_{j=1970}^{1980} \beta_j \times Year_j \times \text{Weak Country}_{c(a)} + \text{Country}_{c(a)} + \text{Year}_{t(a)} + X_a' \gamma + \varepsilon_a$$

As can be seen from Figure 8, for all variables of interest - well CAPEX investment, production and government take, - the interaction terms between the start-up year of an asset and the dummy for weak instiutions become positive and significant in 1974-75, indicating delay in investment, production and payment of taxes in weak countries. To put it differently, investment, production and government take all start exhibiting backloading in mid-70s assets. In fact, the ineraction terms become positive (while not significant) already around 1970, while prior to that there is no consistency in the sign of the estimates, and they are largely insignificant. The results in Figure 8 are, therefore consistent with our above narrative, therefore supporting the causality argument.

While in Figure 8 we focus on the years around the event window and only use the sample from 1949 to 1980, we extend this analysis by aggregating the time dummies to ten 4-years bins and present the results in Table 4. The results are robust to this modification, again, pushing towards a causal interpretation of our results.

TABLE 4

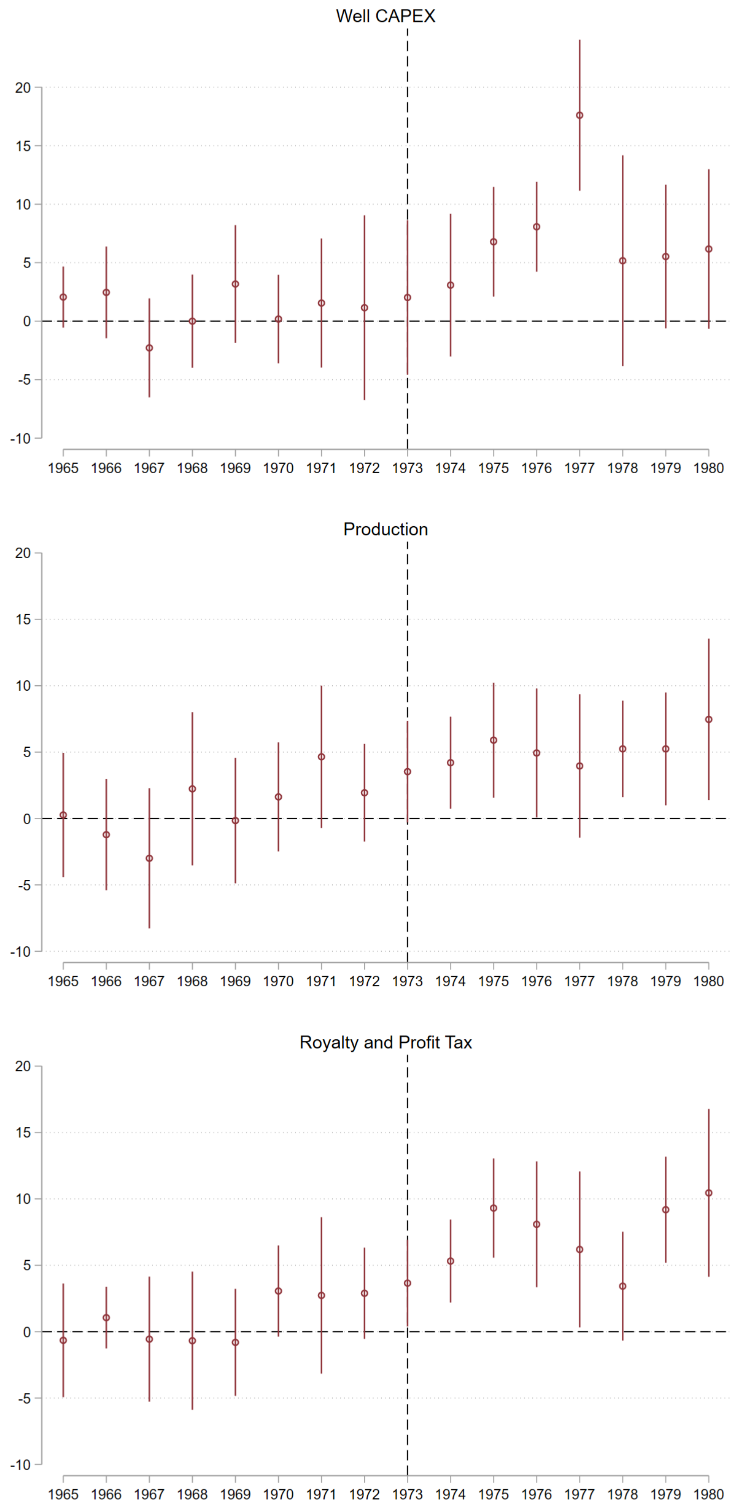
Balance of Power: 66% within 35 Y Weak versus Stong using Polity IV

Diff-in-Diff

	(1) Well Capex 40Y (66%)	(2) Prod 40Y (66%)	(3) Royalty & Profit 40Y (66%)
Weak × Startup Year 1960-63	3.794	1.784	-1.353
	(2.883)	(1.768)	(0.958)
Weak × Startup Year 1964-67	3.506	2.090	-0.827
	(2.097)	(1.808)	(1.186)
Weak × Startup Year 1968-71	3.241	5.071**	1.107
	(1.839)	(1.381)	(1.594)
Weak × Startup Year 1972-75	5.496**	5.946***	3.758*
	(1.910)	(1.144)	(1.580)
Weak × Startup Year 1976-79	9.252*	6.104***	4.404**
	(4.106)	(1.230)	(1.316)
Weak × Startup Year 1980-83	5.561	5.763**	4.502**
	(3.647)	(1.706)	(1.588)
Weak × Startup Year 1984-87	2.876	4.027**	2.056
	(3.380)	(1.139)	(1.221)
Weak × Startup Year 1988-91	4.558*	3.369*	1.837
	(2.267)	(1.433)	(1.193)
Weak × Startup Year 1992-95	3.995	2.837***	1.884**
	(2.659)	(0.684)	(0.712)
Weak × Startup Year 1996-99	3.978	3.102***	2.102*
	(2.697)	(0.814)	(1.003)
N	2275	4014	3291
R-sq	0.46	0.48	0.44

Notes: 1950 - 1959 are baseline years. Year of Start Up fixed effects as well as a country fixed effects are included in all regressions. We also control for firm, climate, fossil fuel type and lifetime of an asset FE as well as Longitude, Latitude and logged physical size of the reservoir. Left hand side variable is indicating the number of years until 66% of total level of well capex investment, production and payments after 35 years is reached. Standard errors in parenthesis clustered by country, Start Up Year and Firm. * stands for statistical significance at the 10% level, ** at the 5% level and *** at the 1% percent level.

Figure 8: Evolution of backloading in countries with weak institutions, Within Asset 35 years (Polity IV)



Notes: Left hand side variable is indicating the number of years until 66% of total level of well capex investment, production and payments after 35 years is reached. 1950 - 1964 are baseline and the years on the x axis indicate the years in which the time dummies in the interaction with weak country dummy take the value 1. Year of Start Up fixed effect as well as a country fixed effects are included in all regressions. We also control for firm, climate and fossil fuel type FE as well as Longitude, Latitude and logged physical size of the reservoir. Standard errors in parenthesis clustered by country and Start Up Year. * stands for statistical significance at the 10% level, ** at the 5% level and *** at the 1% percent level.

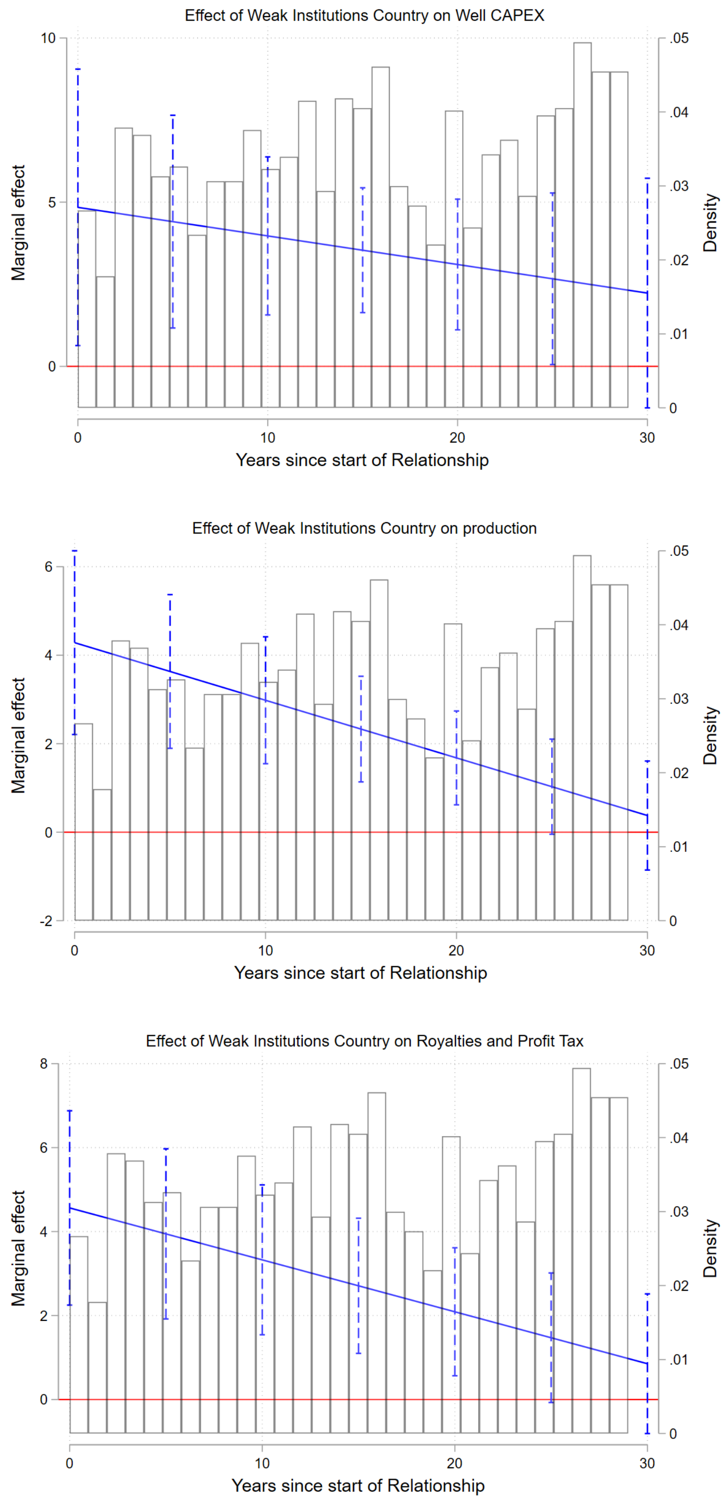
4.3 Backloaded agreements a the relationship level

In the theoretical section we discussed how the investment, production and tax payments may approach the efficient frontierover time. To put it differently, we should expect less backloading as the relationship between a firm and a (weak-institutions) country develops. Here we aim at testing this hypothesis. Assuming that a relationships start in the year in which a firm is awarded a license for the first time in a particular country and resetting the relationships to zero in the 1970 due to the shift in the balance of power documented in previous section, we can evaluate how the time distance in reaching as certain threshold between week and strrong countries changes over the duration of the relationship. To explore this, we interact our Weak country dummy with an asset-level variable proxing the duration of the relationship between the country and the firm at the time this asset starts producing. Formally, we estimate the following specification:

$$y_a = \beta \text{Weak Country} + \alpha \text{Relation Duration}_a + \gamma \text{Weak Country} \times \text{Relation Duration}_a + X_a' \gamma + \varepsilon_a$$

The marginal effects ($\beta + \gamma$Relation Duration) of such as specification are presented in Figure 9. For all variables of interest they exhibit the same pattern: in the beginning of the relationship backloading is positive and significant. At the frist years of the relationship time to reach 66% of well CAPEX investment is delayed by approximately 5 years in weak countries in comparison to countries with strong institutions; this delay is around 4.5 years for production and tax payments. As relationship proceeds, the extent of backloading diminishes. On average, backloading becomes statistically insignificant around 25 to 30 years for all three variables of interest.

Figure 9: Relationship



Notes: Year of Start Up Fixed Effect as well as a country fixed effects are included in all regressions. We also control for year of entrance, firm, climate, fossil fuel type and lifetime of an asset FE as well as Longitude, Latitude and logged physical size of the reservoir. Left hand side variable is indicating the number of years until 66% of total level of well capex investment, production and payments after 35 years is reached. Standard errors in parenthesis clustered by country, Start Up Year and Firm. * stands for statistical significance at the 10% level, ** at the 5% level and *** at the 1% percent level.

4.4 Heterogeneity

In this section we discuss how the heterogeneity in assets characteristics can interact with backloading. We start with comparing backloading in on-shore vs. off-shore assets. One specific feature of an off-shore oil production is that is it technically much more demanding. This makes government expropriation (and subsequent exploitation) of offshore assets less likely. In terms of the model in Section 2, the government in weak institutions country would be facing the following adjusted self-enforcing constraint:

$$GT_t + \delta V_{t+1} \geq GT_t + (1 - C)[(1 - Ł)r(I_t; p_t) - GT_t] \tag{SEoff}$$

where $L < 1$ is the average loss of oil revenue/efficiency in the off-shore assets expropriated and operated by the government in comparison to the firm-operated revenue. For any C, if L is large enough, the constraint SEoff will not be binding. To put it differently, loss of efficiency due to technically demanding nature of off-shore asset operations serves as a commitment device, and makes areements less backloaded for off-shore assets.

A variation of related arguments concerning the difference between off-shore and on-shore assets has been offered by the literature that studies relaitonship between conflicts and locaition of oil fields. For example, Andersen, Nordvik and Tesei (2019) argue that off-shore assets are more difficult to attack, and loot, for the rebel groups, and, thus, they are less likely to be associated with a conflict. Similarly, Nordvik (2018) suggests that off-shore assets do not need as much defence from the potential rebels or political sabotage as the on-shore ones. He shows that onshore-intensive oil countries are more likely to build stronger military to defend their oil assets, and, more likely to suffer from coups as a result. Our argument, while similar in flavour, concerns mostly technological limitations of government, rather than access limitations by domestic rebels.

We test this hypothesis by repeating the exercise behind the Table 3 by location of assets. That is, we estimate the same specification with a indicating an individual asset, but separately for offshore and onshore assets:

$$y_a = \beta \text{Weak Country}_{c(a)} + X_a' \gamma + \varepsilon_a$$

The coefficient β will tell us the difference in the number of years between reaching 66% of production, investment and payments to the government between countries with strong and weak institutions in each of the assets groups. For simplicity, Table 5 provides results only for our main proxy of instiutional strength. As it illustrates, for all our variables of interest we observe backloading in countries with bad instiutions, but not in the countries with good institutions, in line with the discussion above.

TO BE CONTINUED TO DISUCSS NOCs, COLONIAL ORIGIN, ETC.

TABLE 5

66% for 35 Years sample

Panel A: Investment (Well Capex)

	(1) Onshore assets	(2) Offshore assets
Weak (Polity IV)	2.803*	-2.498
	(1.441)	(1.509)
N	922	884
R-sq	0.46	0.23

Panel B: Production

	(1) Onshore assets	(2) Offshore assets
Weak (Polity IV)	2.759**	1.148
	(0.934)	(0.979)
N	1297	1790
R-sq	0.51	0.34

Panel C: Royalty and Profit Tax

	(1) Onshore assets	(2) Offshore assets
Weak (Polity IV)	5.019**	1.230
	(1.688)	(0.984)
N	1154	1313
R-sq	0.40	0.32

Panel D: Government Take (no Sub.)

	(1) Onshore assets	(2) Offshore assets
Weak (Polity IV)	3.210**	1.101
	(1.160)	(1.214)
N	1296	1790
R-sq	0.38	0.30

Notes: Year of Start Up Fixed Effect included in all regressions. We also control for firm, climate and fossil fuel type FE as well as Longitude, Latitude and logged physical size of the reservoir. Left hand side variable is indicating the number of years until 66% of total level of well capex investment, production and payments after 35 years is reached. Standard errors in parenthesis clustered by country, Start Up Year and Firm. * stands for statistical significance at the 10% level, ** at the 5% level and *** at the 1% percent level.

5 Preliminary Conclusion

TO BE ADDED

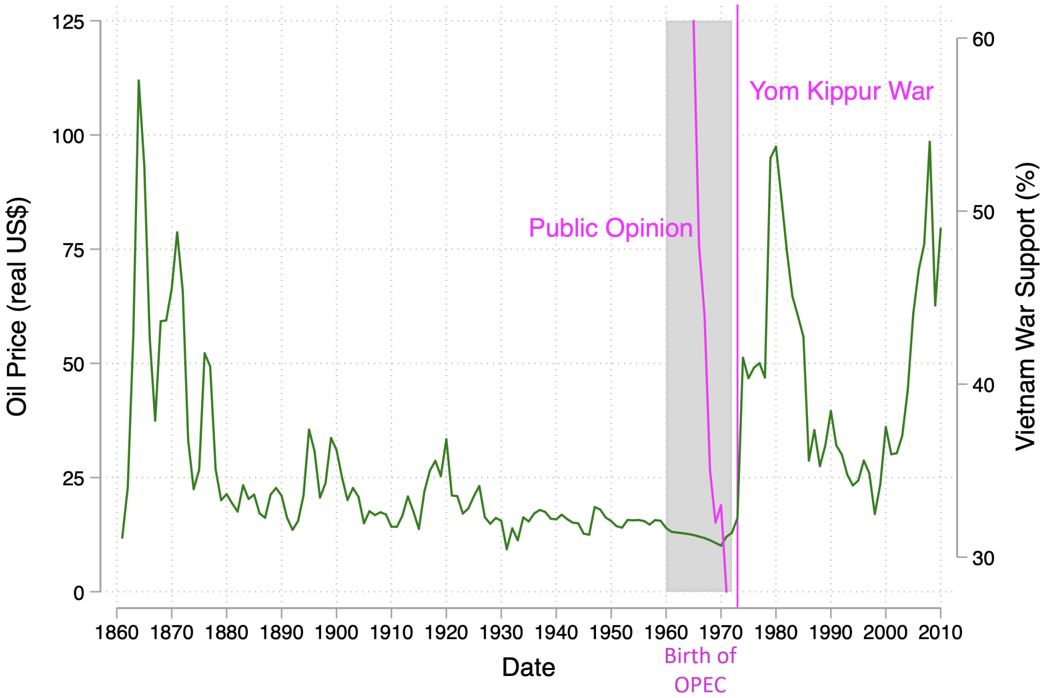
Appendix

A Background information for Section 4.2

In 1919, the U.S. Geological Survey was used to predict that U.S. oil supplies would run out within the next 10 years. Such predictions would turn out to be wrong repeatedly over the next 100 year to come. Still, the prediction triggered the country's first fears of oil depletion. And only two decades later, during WWII, the importance of energy security became apparent once again. Both, it has been argued, Germany and Japan, must have at least partially lost WWII due to their limited access to oil which was essential for the activation of their respective armies. This implied that activities in the oil and gas sector were elevated to become part of national security. A secure source of energy was too important to be left to business men alone. As a con-sequences of the governments involvement, the real price of oil would remain extraordinary stable over the period 1945 to 1970. The automatic stabilizer policy of the US required that any fluctuations in demand would be mirrored by changes in supply with the explicit objective to stabilize the price of oil in order to avoid any disruption in the economic post war recovery.

This agenda implied that the US would, if needed, deploy its army to secure the energy stability and the on-going economic recovery of Western Europe and the US. The most infamous case of US intervention would result in Iran's coup d'etat in the early 1950s and eventually lead up to the 1979 Iranian revolution just two decades later. The situation started unfolding after WWII, when oil rich economies demanded to get a bigger share of the oil rents from the oil majors, typically referred to as Seven Sisters (nowadays consisting of BP, Chevron, Exxon-Mobile and Shell). In particular, the resource rich economies started demanding 50-50 deals. Eventually, Saudi Arabia succeeded in securing such a deal in 1950. When the word of the deal reached Tehran, the accumulated grievances of the people resulted in huge rallies in support of nationalization of the Anglo-Iranian Oil Company (nowadays BP). However, neither BP nor the UK government were interested in giving up the generated oil rents. Eventually, the Iranian government under the leadership of Mohammad Mosaddegh decided to nationalize BP's oil assets. Bound by their energy security goals the US and the UK used their political influence and military force to reduce global take up of Iranian oil. In particular, they would deploy military ships to the Persian Gulf aiming at the restriction of Iranian's exports. The generated loss in revenues triggered the state of bankruptcy such that the initially supported government started loosing support. Eventually, a coup d'etat in 1953 lead to an overthrowing of the Iranian government, replacing an initially democratic government with a monarchical rule of Mohammad Reza Pahlavi which would last until 1979, the next Iranian revolution. Scared by the Iranian example, only few oil rich economies attempted the renegotiation of initially established oil deals with the Seven Sisters throughout the next decade.

This would fundamentally change by 1973 and trigger a shift in the balance of power for two reasons. First, in 1960 Iran, Iraq, Kuwait, Saudi Arabia and Venezuela formally decide to join forces by creating OPEC. The creation of OPEC would allow the members of the group to effectively pursue common political goals as would become clear very soon. Second, after the



beginning of the Vietnam War in 1955, US involvement was steadily increasing until over 20000 US soldiers would be involved in the Vietnam War by 1964. This did not remain unnoticed by the general public and the US government would face domestic resistance with regards to US foreign military involvement. Within this environment, the circumstance surrounding the Yom Kippur War in 1973 revealed the US unwillingness to start yet another. After becoming aware of US military support of Israel during the war, OPEC countries jointly decided to employ oil as one of their most effective weapons and restrict supply to countries which supported Israel, including the US. The economic costs of the oil price shock in the US in 1973 are well documented and many papers have been written on the economic costs of such a negative energy supply shock. Still, despite the evident economic costs, the US and other countries affected, chose not to use military force to respond to the cut in supply. Thus, by 1974 it was apparent to most oil rich economies that future renegotiations with the Seven Sisters would remain unsupported by US military interventions. The game had changed, the balance of power shifted.

B Proofs of Section 2

We solve the stylized model presented in Section 2 and prove the comparative statics in Proposition 2. Note that this model is equivalent to that in Thomas and Worrall (1994) with $C = 0$.

There are multiple SPE equilibria of this repeated game, including the one that gives the parties $(0, 0)$ every period. We will focus on the SPE that lies on the Pareto optimal frontier and that maximizes the firm's profits at the start of the game. We start by restating this Pareto optimization problem in a recursive form. Let V and U be the discounted values of the firm and the government, respectively. We should find a decreasing concave function $U(V)$ (which graphs the Pareto frontier in the (V, U) space as in Figure 2) for each V satisfying the firm's Bellman equation:

$$U(V) = \max_{I,\{V_p\},\{GT_p\}} \{-I + \mathbb{E}[r(I, p) - GT_p + \delta U(V_p)]\} \tag{FBE}$$

where the maximization is subject to the following constraints:
– the government's Bellman equation also known as promise-keeping constraint

$$V = \mathbb{E}[GT_p + \delta V_p], \tag{GBE}$$

– the limited liability constraint for each state p

$$0 \leq GT_p \leq r(I, p), \tag{LL}$$

– the individual rationality constraint for the firm

$$U(V_p) \geq 0. \tag{IR}$$

and the self-enforcing constraint (SE) defined in the text. V_p is the government's discounted value calculated in the period after state p has been realized.

Proof of Proposition 1. In this simple two-state example, $GT_0 = r(I, 0) = 0$ and $GT_1 < r(I, 1)$ - otherwise the firm will incur in losses since it needs to pay I and gets no output with probability 1/2. So the equations (FBE)–(IR) may be rewritten as

$$U(V) = \max_{I,V_0,V_1,GT_1} \left\{-I + \frac{1}{2}\delta U(V_0) + \frac{1}{2}\left(4\sqrt{I} - GT_1 + \delta U(V_1)\right)\right\} \tag{1}$$

subject to

$$V = \frac{1}{2}\delta V_0 + \frac{1}{2}(GT_1 + \delta V_1), \tag{2}$$

$$\delta V_1 \geq (1 - C)\left(4\sqrt{I} - GT_1\right), \tag{3}$$

$$GT_1 \geq 0, \tag{4}$$

$$U(V_1) \geq 0. \tag{5}$$

where (3) is the (SE) for the high price state.

With the strongest possible courts, $C = 1$, (3) is slack and the Pareto set is that of the first-best where $I^* = 1$ and:

$$U(V) = V^{\#} - V, \text{ where } V^{\#} = \frac{1}{1 - \delta}. \tag{6}$$

Otherwise, the Pareto set would be smaller: $U(V) \leq V^{\#} - V$, $V \in [V_{\min}, V_{\max}]$.

We solve the problem for any C. We find GT_1 from (2),

$$GT_1 = 2V - \delta V_0 - \delta V_1, \tag{7}$$

and plug (7) into (1), (3) and (4), the equations (1)–(5) are restated as follows:

$$U(V) = \max_{I,V_0,V_1} \left\{ 2\sqrt{I} - I - V + \frac{\delta}{2}\left(V_0 + V_1 + U(V_0) + U(V_1)\right) \right\} \tag{8}$$

subject to

$$\delta V_1 - (1-C)\left(4\sqrt{I} - 2V + \delta V_0 + \delta V_1\right) \geq 0, \tag{9}$$

$$2V - \delta V_0 - \delta V_1 \geq 0, \tag{10}$$

$$U(V_1) \geq 0. \tag{11}$$

Note that (8) contains the firm's expected profit for one period: $2\sqrt{I} - I - \left(V - \delta\frac{V_0+V_1}{2}\right)$ and the firm's expected profits of future periods: $\delta\frac{U(V_0)+U(V_1)}{2}$. Note that V is the government take over all periods so we need to subtract $\delta\frac{V_0+V_1}{2}$ which is the discounted sum of all future government takes from tomorrow onwards.

Let $\lambda, \mu, \nu \geq 0$ be the Lagrange multipliers for (9), (10) and (11), respectively. Then the first-order conditions for (8)–(11) are

$$I = (1 - 2\lambda(1-C))^2, \tag{12}$$

$$U'(V_0) = -1 + 2\lambda(1-C) + 2\mu, \tag{13}$$

$$U'(V_1) = \frac{-1 - 2\lambda C + 2\mu}{1 + 2\frac{\nu}{\delta}}. \tag{14}$$

A last condition follows from the envelope theorem applied to the problem (8)–(11):

$$U'(V) = -1 + 2\lambda(1-C) + 2\mu = U'(V_0). \tag{15}$$

If $U(\cdot)$ is strictly concave, then $U'(V_0) = U'(V)$ implies $V_0 = V$ (this not necessarily true where $U(\cdot)$ is linear) and we can use this to simplify (8)–(10). Note as well that, $-1 \leq U'(V) \leq 0$ - we focus on the Pareto frontier so $U'(V) \leq 0$ and $U'(V) = -1$ when (8) and (10) are slack.

Finally, we want to show that $V_1 \geq V$ by showing $U'(V) \geq U'(V_1)$:

$$-1 + 2\lambda(1-C) + 2\mu \geq \frac{-1 - 2\lambda C + 2\mu}{1 + 2\frac{\nu}{\delta}} \tag{16}$$

$$\lambda + \frac{\nu}{\delta}\left(-1 + 2\lambda(1-C) + 2\mu\right) \geq 0 \tag{17}$$

$$\lambda + \frac{\nu}{\delta}U'(V) \geq 0 \tag{18}$$

If (SE) binds ($\lambda > 0$), we have strict backloading $V_1 > V$.

So far we have shown that the firm increases V following a high price. To understand how is this value given, we need to characterize the optimal investment and government take. For this, we need to solve for $U(V)$ by guessing that it is piecewise quadratic and verifying that the guess is correct. We consider two cases depending on the parameters.

Case 1

First, suppose that (SE) in (9) does not bind for some V. Then $\lambda = 0$ which implies $I = 1$ (the first-best level of investment). Suppose that $U(\cdot)$ contains a part of the first-best Pareto frontier:

$$U(V) = V^{\#} - V \tag{19}$$

where $V^{\#} = \dfrac{1}{1-\delta}$. Plugging this assumption to the right-hand side of (8), we see that (19) indeed holds if (9–11) hold. In particular, (9) holds for large V, large[12] V_1 and small V_0.[13] This means that if we are interested in the broadest set of V in which all the constraints hold, we need to set $V_1 = V^{\#}$ and $V_0 = V = V^*$ where V^* is the (possible) left boundary of the first best set determined by equalizing (9) with $V_1 = V^{\#}$ and $V_0 = V = V^*$:

$$V^* = \frac{4(1-C) - (4-3C))\delta}{(1-C)(1-\delta)(2-\delta)}. \tag{20}$$

However, there is another constraint (10) which bounds V_1 from above. In particular, if $V_0 = V$ then (10) implies that

$$V \le V_1 \le \frac{V}{\beta} \quad \text{where } \beta = \frac{\delta}{2-\delta}. \tag{21}$$

If $V^* < \beta V^{\#}$ then the point $(V^*, \beta V^{\#} - V^*)$ in plane (V, U) is not feasible. Then (21) binds, so $V_1 = V/\beta$ should be put into (9). Then the first best Pareto frontier is feasible for $V \ge \tilde{V}$ where $\tilde{V}$ determined by equalizing (9) with $V_1 = V/\beta$ and $V_0 = V = \tilde{V}$:

$$\tilde{V} = \frac{4(1-C)}{2-\delta}. \tag{22}$$

Thus we have Case 1 is divided into two sub-cases, 1.1 and 1.2:

Case 1.1. $\delta \ge \dfrac{4(1-C)}{1+4(1-C)} \Leftrightarrow V^* \le \tilde{V} \Rightarrow$ the first-best part of the Pareto frontier needs more than one step to cross from the left to the right. Then the segment of the Pareto set neighboring from the left to its first-best part is determined by equalizing (9) with $V_1 = V/\beta$, $V_0 = V$ and $U(V_1) = V^{\#} - V_1$. Solving (8) for $U(V)$, we obtain

$$U(V) = aV^2 + bV + c \tag{23}$$

where

$$a = -\frac{2-\delta}{8(1-C)^2}, \quad b = \frac{1}{1-C} - 1, \quad c = \frac{\beta}{1-\delta}. \tag{24}$$

The level of investment is

$$I(V) = \left(\frac{2-\delta}{4(1-C)}V\right)^2. \tag{25}$$

Equations (23)–(25) are valid for Case 1.1 and $V \in [\beta\tilde{V}, \tilde{V}]$. To the right of this segment $[\beta\tilde{V}, \tilde{V}]$,

[12] Making V_1 larger is not necessary if $L = 1$.

[13] Note that $U'(V_0) = U'(V)$ regardless of which constraints bind. This does not imply $V_0 = V$ if the point $(V, U(V))$ is in the first-best part of the Pareto frontier because then $U'(V) = -1$ everywhere.

we have the following solution: $U(V) = V^{\#} - V$, $V_1 = V^{\#}$ and $I = 1$ for $V \in [\tilde{V}, V^{\#}]$. To the left of this segment $[\beta\tilde{V}, \tilde{V}]$, we have Equations (34)–(37) for $V \in [\beta^2\tilde{V}, \beta\tilde{V}]$ where $k = 2$. We go on until $V_{\min}$ pinned down by the equation (39) below where k is such that $V_{\min}$ is between $\beta^k\tilde{V}$ and $\beta^{k-1}\tilde{V}$.

Case 1.2. $\frac{2(1-C)}{1+2(1-C)} \leq \delta < \frac{4(1-C)}{1+4(1-C)} \Leftrightarrow \tilde{V} \leq V^* \leq V^{\#} \Rightarrow$ the first-best part of the Pareto frontier needs less than one step to cross. This means that there are points $(V, U(V))$ in the second-best part of the Pareto frontier (i.e. where $U(V) < V^{\#} - V$) such that the constraint (11) binds i.e. we jump to the first best frontier following a good shock: $V_1 = V^{\#}$. This is equivalent to $V^* \geq \tilde{V}$ and to $V^* \geq \beta V^{\#}$. Then the segment of the Pareto set neighboring from the left to its first-best part is determined by equalizing (9) with $V_1 = \min(V/\beta, V^{\#})$,[14] $V_0 = V$ and $U(V_1) = V^{\#} - V_1$. Solving (8) for $U(V)$, we obtain

$$U(V) = aV^2 + bV + c \tag{26}$$

where a, b, c are given by

$$a = -\frac{2-\delta}{8}, \quad b = -\frac{C}{4(1-C)}\frac{\delta}{1-\delta}, \quad c = \frac{\beta}{(1-C)(1-\delta)}\left(1 - \frac{\delta}{1-\delta}\frac{C^2}{8(1-C)}\right), \tag{27}$$

with the level of investment given by

$$I(V) = \left(\frac{C}{4(1-C)}\frac{\delta}{1-\delta} + \frac{2-\delta}{4}V\right)^2 \tag{28}$$

for $V \in [\beta V^*, V^*]$ and by (24), with investment given by (25), for $V \in [\beta V^*, V^*]$. The complete solution starting with the highest possible value for the government is:

* $[V^*, V^{\#}]$ has $I = 1, V_1 = V^{\#}, U(V)$ by (19)
* $[\beta V^{\#}, V^*]$ has I by (28), $V_1 = V^{\#}, U(V)$ by (26) and (15) and (17) bind
* $[\beta V^*, \beta V^{\#}]$ has I by (25), $V_1 = \frac{V}{\beta}, U(V)$ by (23) and (15) and (16) bind
* $\left[\beta^2 V^{\#}, \beta V^*\right]$ has I by (33)=(25), $V_1 = \frac{V}{\beta}$, $U(V)$ by (34) with $k = 2$ and a, b, c by (27)
* $\left[\beta^2 V^*, \beta^2 V^{\#}\right]$ has I by (33), $V_1 = \frac{V}{\beta}$, $U(V)$ by (34) with $k = 2$ and a, b, c by (24). And so on.

Case 2.

This case arises when $\delta < \frac{2(1-C)}{1+2(1-C)} \Leftrightarrow V^* > V^{\#} \Rightarrow$ the Pareto frontier has no first-best part. Then the right boundary of the Pareto frontier is determined by equalizing (8) and (9) with $V_0 = V_1 = V$ and $U(V) = 0$:

$$\hat{V} = \frac{8(1-C)\delta}{M^2} \quad \text{where } M = \delta + 2(1-C)(1-\delta). \tag{29}$$

The most rightward segment of the Pareto set is determined by equalizing (9) with $V_1 = \hat{V}$,

[14] We need to include V/β to get the full-length segment $[\beta V^*, V^*]$ (which is convenient for writing general formulas). Hence (10) binds and (11) is slack in the left part of the segment where $V \leq \beta V^{\#}$.

$V_0 = V$ and $U(V_1) = 0$. Solving (8) for $U(V)$, we obtain

$$U(V) = aV^2 + bV + c \tag{30}$$

where

$$a = -\frac{2-\delta}{8}, \quad b = -\frac{2\delta^2 C}{M^2}, \quad c = \frac{8(1-C)\delta^2}{M^4}(C\delta + M). \tag{31}$$

The level of investment is

$$I(V) = \left(\frac{2\delta^2 C}{M^2} + \frac{2-\delta}{4}V\right)^2. \tag{32}$$

Equations (30)–(32) are valid for Case 2 and $V \in [\beta\hat{V}, \hat{V}]$.

For lower V (i.e. to the left of the segments considered above, that is, to the left of $\beta\hat{V}$ in case 2, βV^* in case 1.2 and $\beta\tilde{V}$ in case 1.1), both (9) and (10) bind. Then

$$V_1 = \frac{V}{\beta}, \quad I = \left(\frac{(2-\delta)V}{4(1-C)}\right)^2 \tag{33}$$

and the formula for $U(V)$ depends on $k \geq 2$, the number of steps (made in good periods) needed to reach the first best area (or the final position $\hat{V}$ in Case 2):

$$U(V) = a_k V^2 + b_k V + c_k \tag{34}$$

where a_k, b_k, c_k can be determined recursively from the Bellman equation (8):

$$a_k = \frac{a_{k-1}}{\beta} - \frac{2-\delta}{8(1-C)^2}, \quad b_k = b_{k-1} + \frac{1}{1-C}, \quad c_k = \beta c_{k-1}, \quad a_1 = a, \quad b_1 = b, \quad c_1 = c, \tag{35}$$

where a, b, c are defined in (24), (27) or (31), depending on the case (1.1, 1.2 or 2) whence

$$a_k = \beta^{1-k}a - \frac{\beta^{1-k}-1}{\beta^{-1}-1}\frac{2-\delta}{8(1-C)^2}, \quad b_k = b + \frac{k-1}{1-C}, \quad c_k = \beta^{k-1}c. \tag{36}$$

In order to compute this coefficients, we need to take the following steps. Take case 1.2, for example. We need to compute the segment to the left of $[\beta V^*, V^*]$. Using (33), the minimum V associated to the maximum $V_1 = \beta V^*$ is then: $\beta^2 V^* = V$. Then we take a V in $[\beta^2 V^*, \beta V^*]$ with associated $V_1 = \beta V^*$ and $U(V_1)$ defined by (29)-(30) and I as in (28) for $V \in [\beta V^\#, V^*]$ and by (25), for $V \in [\beta V^*, \beta V^\#]$. We plug in this in (14) and find a_2, b_2, c_2. In general, k is given by

$$k = \left\lceil \frac{\ln\left(V/\bar{V}\right)}{\ln \beta} \right\rceil \tag{37}$$

where (37) is determined by $V = \beta^k \bar{V}$ and $\bar{V} = \tilde{V}$ for Case 1.1, $\bar{V} = V^*$ for Case 1.2 and $\bar{V} = \hat{V}$ for Case 2.

Let n be the number of steps needed to reach the final position in the Pareto set at which $U(V) = 0$. After we reach to V^* or $\tilde{V}$, then we get to $V_1 = V^\#$ for cases 1.2 and 2 (where $V_1 = \hat{V}$) and we need more than one step to reach $V^\#$ for case 1.1. Eventually, we get to $U(V) = 0$ for sure in all cases.

Clearly, n is given by (37), with $\bar{V} = V^{\#}$ for Case 1 (so $n \geq k$ in this case) and $\bar{V} = \hat{V}$ for Case 2 (so $n = k$ in this case). Then the Pareto optimal path for a given initial V looks as follows: at the first $n-1$ good periods (bad ones are not taken into account since the investment stays constant and $GT_0 = 0$), $GT_1 = 0$ and the investment increases exponentially at rate $\frac{1-\beta^2}{\beta^2}$. To see this, we look at the increase of investment from V to $V_1 = \dfrac{V}{\beta}$ this is:

$$\frac{\frac{1}{\beta^2}\left(\frac{(2-\delta)V}{4(1-C)}\right)^2 - \left(\frac{(2-\delta)V}{4(1-C)}\right)^2}{\left(\frac{(2-\delta)V}{4(1-C)}\right)^2} = \frac{1-\beta^2}{\beta^2}$$

Then there is one period of decreased growth of investment and some positive government take, and finally, GT_1 defined by (7) in all the possible segments, with $V = V_0 = V_1 = V^{\#}$ in case 1 and $V = V_0 = V_1 = \hat{V}$ in case 2, so $GT_1 = 2(1-\delta)V$, i.e. $GT_1 = 2$ in case 1 and $GT = 2(1-\delta)\hat{V}$ in case 2 for the stabilized regime and I stabilize at their maximal levels and remain constant forever. In particular, in Case 1, the stabilized level of investment is first-best optimal.

In Case 2, the final stable level of I is not first-best optimal and depends on the parameters:

$$\hat{I}_{\max} = \left(\frac{2\delta}{M}\right)^2. \tag{38}$$

where (38) comes from plugging $\hat{V}$ in (32). Expectedly, the stabilized level of investment is higher for higher δ and lower L. Note also that the same is true about the time of stabilization n. The stabilized level of government take in Case 2 is decreasing in $(1-C)$: if $(1-C)$ is too high, the possibility to expropriate is overwhelmed by the lack of trust. The maximum level of government take happens when $V = V_0 = V_1 = \hat{V}$ so $GT_1 = 2\hat{V}\,(1-\delta) = \dfrac{16(1-C)\delta\,(1-\delta)}{(\delta + 2(1-C)(1-\delta))^2}$.

In both cases, the left bound of the Pareto frontier $V_{\min}$ is positive (this fact follows from $b_k > 0$) and reached at the maximum of $U(V)$, when $U'(V) = 0$ i.e.

$$V_{\min} = \frac{b_k}{-2a_k} \tag{39}$$

where k is such that $V_{\min}$ is between $\beta^k\bar{V}$ and $\beta^{k-1}\bar{V}$ where $\bar{V}$ depends on the case as before.

Proof of Proposition 2. In this proof, we perform comparative statics with respect to C to show that the smaller C the more backloaded is the contract. In case 1.1, on each segment

k the peak of the k-th parabola (whose part is the graph of $U(V)$ for V from this segment) is

$$\begin{aligned}
\frac{b_k}{-2a_k} &= \frac{b+\dfrac{k-1}{(1-C)}}{-2\left(\beta^{1-k}a-\dfrac{\beta^{1-k}-1}{\beta^{-1}-1}\dfrac{2-\delta}{8(1-C)^2}\right)} \\
&= \frac{\dfrac{1}{(1-C)}-1+\dfrac{k-1}{(1-C)}}{-2\left(\beta^{1-k}\left(-\dfrac{2-\delta}{8(1-C)^2}\right)-\dfrac{\beta^{1-k}-1}{\beta^{-1}-1}\dfrac{2-\delta}{8(1-C)^2}\right)} \\
&= 4(1-C)\beta^{k-1}\frac{\beta-1}{\delta-2}\frac{(1-C)-k}{\beta^k-1} \\
&= 8\frac{\beta^{k-1}}{1-\beta^k}\frac{1-\delta}{(\delta-2)^2}(1-C)\left(k-(1-C)\right)
\end{aligned}$$

Note that these Vs are proportional to $(1-C)\left(k-(1-C)\right)$ which is increasing in $(1-C)$ for $k \geq 2$. One of these peaks is really the global max because $U(V)$ is concave. So $V_{\min}$ is either at this peak or at the boundary between some two neighboring segments (in which case, $U(V)$ has a kink at $V_{\min}$). Hence, the max of $U(V)$ is increasing in $(1-C)$ (remember that U is concave; also one needs to consider the special case $k=1$ to complete the proof). Since β, the size of the step, does not depend on $(1-C)$, we conclude that the number of steps with $GT=0$ is decreasing in $(1-C)$ since we start from the best point from the firm's viewpoint.This logic apply to the other cases as well.

The "false" peaks in $U(V)$ are increasing in k for each fixed k. The k at which the peak is global (i.e. the peak determined by (39) is in the k-th segment, so it is the argmax of $U(\cdot)$) is decreasing in $(1-C)$.

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