I'll Pay You Later: Backloading to Sustain Opportunistic Relationships

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Abstract

In 1967, a decline in the use of military interventions by major world powers undermined international contract enforcement and increased the expropriation risk in many developing countries. Using data from the oil and gas industry, we document that this change caused backloading - a delay in investment, production and taxation - just as predicted by the theory of self-enforcing agreements. The delay peaked at five years right after 1967 and vanished as the firm-government relationship matured. On average, the government lost 120 Million US$ per year due to this delay, or roughly 8% of the collected taxes.

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"Perhaps decolonization and the general postwar weakening of the OECD members as political and military actors is an experiment where expropriation is first viewed as impossible and then becomes possible."
— Eaton, Gersovitz and Herring (1983)

1 Introduction

The international commercial relations had traditionally been upheld by the implicit or explicit backing of open warfare. By the late 1960s, a decline in the military interventions by major powers weakened the international contract enforcement triggering the largest expropriation wave in recent history (Kobrin, 1980; Hajzler, 2012). Adverse outcomes resulting from imperfect contract enforcement are common in a wide range of contexts (North, 1991; Djankov et al., 2003). However, this problem is particularly salient in contracts with the government since it often has the power to undermine the rule of law. Weak institutions further exacerbate contracting frictions, making resource-rich economies unable to exploit their natural resources and move out of poverty (Van der Ploeg, 2011; Venables, 2016).

Despite the deterioration in international contract enforcement, expropriation of foreign assets has remained rare. Even during the aforementioned largest expropriation wave, less than 5% of all foreign-owned firms were expropriated in developing countries (Kobrin, 1980). Moreover, the share of global foreign direct investment going to the developing world has been on an upward trend since the 1970s, exceeding 52% in 2021 (UNCTAD, 2022). How have firms and governments managed to avoid the fate of expropriation while keeping cross-country investments flowing?

In this paper, we argue that firms and governments mitigate these expropriation threats by establishing self-enforcing agreements (MacLeod and Malcomson, 1989; Baker, Gibbons and Murphy, 1994). In theory, in these agreements, the firm reduces the expropriation incentives by delaying investing and paying taxes ("backloading") to increase the government's future value from the relationship (e.g., see

Ray (2002) for a general model). We exploit a historical natural experiment in the deterioration of international contract enforcement in combination with rich data from the oil and gas industry, to identify the emergence, and estimate the extent of contract backloading. Despite the existence of large theoretical literature (see literature review), empirical analysis of such contract dynamics has been challenging due to data unavailability and identification problems. Our paper is the first to overcome both issues.

To guide the empirical analysis, we present a model of an ongoing relationship between a government and a firm. Our model builds on a stylized version of Thomas and Worrall (1994) and explicitly introduces variation in formal contract enforcement. In the model, the government can attempt to expropriate, while the probability of success is determined by the strength of formal institutions. To avoid expropriations, the government's immediate expropriation gains need to be less valuable than the expected long-term gains from having the firm invest and pay taxes. We show that the government's incentive to expropriate, and the resulting contract backloading, increase as the quality of institutions deteriorates.

We test this prediction in an important sector, the oil & gas industry. We use data from Rystad Energy, an energy consultancy, which contains detailed information on the financial, geographical and geological characteristics of fields operated by the seven largest multinational firms, the so-called oil majors. Our dataset covers fields which started production between 1960 and 1999, adding up to 3494 fields, 124 country-firm combinations and 49 countries. We differentiate the quality of institutions across countries by using the *level of constraints imposed on the executives* from Polity IV, but our results are robust to a number of alternative institutional measures. The oil & gas sector is a particularly well-suited setting to study imperfect contract enforcement. First, it is the most capital intensive industry (Ross, 2012), making the expropriation threat particularly salient. Second, petro-rich economies vary greatly in the quality of their formal institutions, providing the necessary cross-sectional variation to evaluate the need for backloading. Finally, relationships between oil firms and hosting states span decades, allowing us to study relationship dynamics over a long period of time.

We consistently measure backloading across fields, despite their different characteristics, by analyzing the accumulation of investment, production and tax payment over the first 35 years of a field's life. Specifically, we compare the time it takes to reach two thirds of these cumulative flows between countries with weak and strong institutions. Focusing on the subsample with an increased threat of expropriation (i.e. after 1973), we find that investment, production and tax payments in countries with weak institutions are backloaded by an average of two years relative to countries with strong institutions. A back-of-the-envelope calculation using these stylized facts suggests that in present value terms, a country with weak institutions loses on average 120 Million US$ per year due to this delay.[1]

To establish that the delay is causally driven by the increased expropriation threat, rather than by the general difficulties of doing business in countries with weak institutions (such as poor infrastructure, red tape and corruption), we exploit the historical global change in international relations. From 1967 to 1973, the world experienced a transition, in which *"expropriation is first viewed as impossible and then becomes possible"* (Eaton, Gersovitz and Herring, 1983). Prior to 1967, major developed nations threatened, or simply used, their military power to enforce the contracts of their firms.[2] But during the 1967-1973 transition, the home governments of the multinational firms permanently reduced the use of their

[1]Fields in countries with weak institutions produce on average in 30 years the same amount as the fields in countries with strong institutions do in 28 years. Using group-specific production dynamics, we allocate total output to individual periods, accounting for the two-year difference in the lifetime. The price of the resource and the interest rate are assumed to be constant across space and time. With an assumed interest rate of 5%, 10% or 15%, the NPV of a field is 5%, 8% or 10% larger in countries with strong institutions. Since the average NPV of field level tax payments in countries with weak institutions is 1 billion US$, the delay implies that the country would have gained on average 80 Million US$ more per field without a delay. This translates into 120 Million US$ per country and year since oil majors start 1-2 fields per year in countries with weak institutions.

[2]Perhaps the most infamous example is the coup d'etat against Iranian prime minister Mohammad Mossadegh, backed by the CIA and Britain's MI6, who attempted to renegotiate the contract with the Anglo Persian Oil Company (nowadays BP) in 1953. As the British officials at the Ministry of Fuel and Power put it in September 1951: "If we reached settlement on Mussadiq's (sic) terms, we would jeopardize not only British but also American oil interests throughout the world. We would destroy prospects of the investments of foreign capital in backward countries. We would strike a fatal blow to international law. We have a duty to stay and use force to protect our interest" (Abrahamian, 2013). In response to the Iranian nationalization, the US and the UK used their political influence and military force to reduce the global uptake of Iranian oil, resulting in a loss in government revenues and an eventual successful coup d'etat.

military power. Specifically, we document that the average number of military interventions by the US, the UK and France fell from 2.4 per year to 1 per year between 1966 and 1967. The reasons for this change are 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 dangers and costs of challenging the United States were less than they had been in the past, [...] while the gains could be considerable"* (p.565).

In terms of our model, the use of military power can be thought of as an external enforcement substitute for strong formal institutions. Thus, the decline in military coercion weakened enforcement and triggered the need for agreements to be backloaded to counteract the increased threat of expropriation. Driven by this reasoning, we compare similar oil and gas fields in countries with weak institutions relative to countries with strong institutions between 1960 and 1980 using a Difference-in-Differences framework. We find that prior to 1967, backloading in financial and physical flows was similar in these two groups of countries. However, after 1967 they became delayed by 5 years in countries with weak institutions relative to their counterparts. Moreover, just after 1967, countries with weak institutions started lagging in the number of fields acquired by the oil majors and the time between awarding a field license and the start of production. These results are consistent with the idea that oil majors backloaded the agreements to adjust to the increased threat of expropriation. We support these findings with a battery of robustness checks and a number of case studies.

We test a second prediction of the theory on the long-term dynamics of firm-government relationships. As the relationship matures, backloading vanishes because the higher future taxes need to be paid eventually, which gives the government enough rents such that it no longer wants to expropriate. Our estimates are consistent with this prediction. Fields at the start of the relationship exhibit a delay of 4-5 years. As the relationship matures, backloading vanishes. In particular, after 25 years of the relationship, the initially significant difference in backloading disappears. Thus, the 2-year delay, reported as a stylized fact, represents a weighted average of mature and young relationships in our sample.

The findings of this paper contribute to the literature on self-enforcing contracts. Backloading is optimal in a variety of settings without commitment and limited transferable payoffs (in addition to Thomas and Worrall (1994), see Lazear (1981) and Fong and Li (2017) for wage backloading in a labor relationship, Fuchs, Green and Levine (forthcoming) for loan backloading in a lending relationship and Acemoglu, Golosov and Tsyvinski (2008) for backloading in rent-seeking in a political economy setting, just to name a few).[3] Yet, the progress of the empirical literature has been limited by the unavailability of transaction data in these informal environments (Antràs and Foley (2015), Macchiavello and Morjaria (2015, 2021), Calzolari et al. (2021) - see Gil and Zanarone (2017) for a survey). To the best of our knowledge, we are the first to provide empirical evidence of contract backloading.[4] Further, unlike the previous empirical literature, we study relational contracting in the government-firm relationship rather than in inter and intra-firm relationship. More specifically, we are the first to document the use of self-enforcing relationships between firms and governments aimed to overcome the lack of formal institutions.

We also contribute to the literature that studies the link between institutions and firms' decisions such as their organization (Lafontaine, Perrigot and Wilson, 2017), their extent of state ownership (Aldashev, Rantakari and Zanarone, 2023) or their performance (Levy and Spiller, 1994). Within this literature, the closest contributions to our paper focus on the oil industry. In Guriev, Kolotilin and Sonin (2011), the firm not honoring the tax payments leads to the government's expropriation, while in Stroebel and Van Benthem (2013) the firm insures the government against oil price volatility by smoothing tax flow. Both papers focus on a stationary equilibrium and find that expropriations are more likely under weak institutions. In Jaakkola, Spiro and Van Benthem (2019), the firm can

[3] There are alternative theories rationalizing contract backloading in settings with asymmetric information (see Ghosh and Ray (2022) for an overview). In section 4.2, we discuss why we believe those do not apply to our setting.

[4] Brugues (2020) finds backloading in linear-pricing contracts in Ecuador; however, the setting is different from ours because the sellers can commit to such contracts.

invest again after an expropriation and find that taxation and investment exhibit cycles and that such cycles are more persistent under strong institutions. Unlike the above papers, our model studies the non-stationary dynamics of the firm-government relationships and our empirical analysis explicitly accounts for firm-level characteristics.

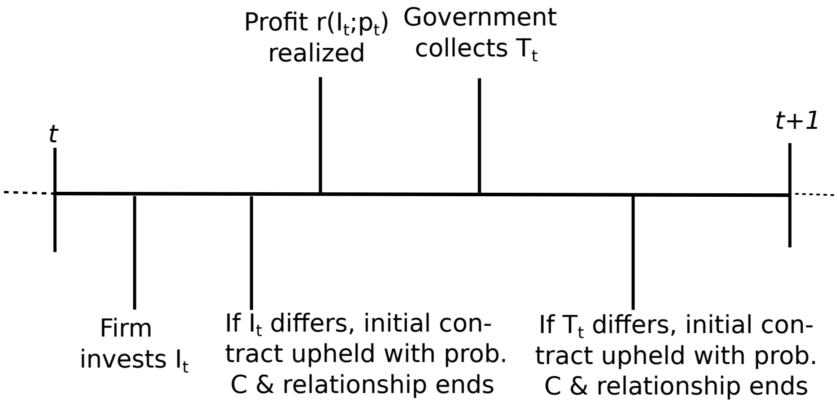
More generally, this paper also adds to the development literature identifying a novel channel through which institutions affect investment, and thereby growth. It is widely recognized that absence of strong institutions undermines incentives to invest, eroding a country's strive for economic prosperity (North (1991), Robinson and Acemoglu (2012), see Baland et al. (2020) for an overview). However, the knowledge on the specific empirical channels of this mechanism remains relatively limited (Besley and Mueller, 2018). For example, in the context of natural resource investment, firms are less likely to explore oil and gas fields (Cust and Harding, 2020) and start production (Mihalyi, 2021) in resource rich developing economies with weak institutions. We contribute to this literature by establishing that weaker institutions delay investment and production - that is, conditional on a field being developed, oil and gas extraction takes longer in countries with weaker institutions. In a broader sense, our paper provides an important insight for policies promoting the development of countries with weak institutions. We show that the use of backloading could counteract the detrimental effects of weak contract enforcement, ultimately enabling the realization of investment that might not have been possible otherwise.

In the next section, we set up the model and derive our main hypotheses. In section 3, we describe the data and present the stylized facts. In section 4, we present our empirical results before we conclude in section 5. Additional results, robustness checks and case studies are relegated to the online Appendix.

2 Theory

To guide our empirical predictions, we present a stylized model of an ongoing informal relationship between a government and a firm. It is based on an extended

Figure 1: Timeline



version of Thomas and Worrall (1994) by explicitly modeling the legal constraints on the parties' ability to break the contract. All the proofs are relegated to Appendix A.

In the model, the government and the firm interact repeatedly over an infinite number of periods. The firm invests and pays taxes, while the government decides whether to expropriate or not. The timeline is shown in Figure 1. Every period, the government and the firm agree on an investment I_t and tax payment T_t. Then, the firm invests I_t which depreciates within one period.[5] When the firm does not invest as agreed, the courts upholds the initial agreement with probability $C \in [0, 1]$ and, with probability $1 - C$, the government expropriates the firm. Next, an *i.i.d.* price is realized whereby with equal probabilities the price can be low ($p = 0$) or high ($p = 1$). Jointly, the price and investment determine the revenues $r(I_t; p_t) = 4p_t\sqrt{I_t}$. Then the government chooses a tax payment T_t, leaving the firm a net profit of $r(I_t; p_t) - T_t$. If the government collects a different T_t from the one agreed, the initial agreement is upheld with probability C. We assume that after any deviation the relationship ends.

The government and the firm have perfect information about each other actions. They both discount the future with δ, have zero outside options and are

[5]Capital accumulation does not qualitatively change the nature of the game (Thomas and Worrall, 1994).

credit-constrained: $r(I_t;p_t) - T_t \geq 0$ and $T_t \geq 0$.[6] The expected value functions of the government V_t and the firm U_t are:

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

An agreement $A{=}(I_t, T_t)$ at time t depends on the history up to time $t-1$ and the current realization of the price. The agreement needs to be self-enforcing so that neither the government nor the firm have an incentive to violate it ex-post. The assumptions about the consequences of deviations imply that (1) the firm never deviates from investing the agreed amount, and (2) if the government deviates, it tries to expropriate all the profits.[7] As a result, A is self-enforcing if the government has incentives to honor the agreement. The following condition ensures this at time t, for a given p_t and C:

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

This constraint requires that the discounted future value of the relationship for the government δV_{t+1} (in terms of future taxes) be at least as large as the expropriated gains today. If $C = 1$, the agreement is perfectly enforced by the courts and (SE) is slack. If $C = 0$, there is no legal enforcement, as in Thomas and Worrall (1994), and the agreement has to be self-enforced to be sustainable.

As a benchmark, consider the optimal contract under perfect enforcement. Define I^* as the efficient total surplus-maximizing level of investment determined by $E\left[r'(I^*;p_t)\right] = 1$. The firm invests I^* every period and the tax payments determine how the surplus is shared but have no effect on the level of investment.

[6] Unrestricted upfront transfers from the government ($T_t < 0$) eliminate the hold-up problem by subsidizing the cost of investment before it is incurred (i.e. the firm "sells" the company). In the oil & gas industry, upfront transfers are very rare. Figure C.2 shows that the share of subsidies relative to the total cost of production (within the first seven years of production) is below 8%.

[7] The former follows from the observation that a deviation, if not upheld by court, leads to a complete expropriation, and the firm can always guarantee itself a zero payoff by not entering the country. The latter holds since the firm never invests again following the government's deviation.

We focus on the Pareto efficient equilibrium that maximizes the firm's payoff at the beginning of the game, as in Thomas and Worrall (1994).[8] The contract that maximizes the firm's payoff features no transfers to the government which receives its outside option. Therefore, with perfect enforcement, the optimal agreement is stationary and gives the same value to the government and the firm every period.

If enforcement is imperfect such that (SE) binds, the efficient level of investment is not reached immediately. Instead, the agreement A is "backloaded", that is, the government's future value from the relationship V_{t+1} increases over time.[9] The firm achieves this by progressively increasing investment until I^* is reached. The initial under-investment is driven by the profit-maximizing behavior of the firm. Note that (SE) could be satisfied by paying a sufficiently large tax from the first period onward. However, the firm can do better by using the promise of larger future taxes to deter expropriations at the beginning of the relationship. Thus, it is optimal not to have tax payments until the period before I^* is reached. Intuitively, delaying taxes and investments makes the threat of terminating the relationship more costly to the government and hence, more effective, which increases the government's credibility:

Proposition 1. *In institutional environments where the self-enforcing constraint (SE) binds, investment and production increase over time to reach the efficient steady-state value at which (SE) no longer binds. Tax payments are zero until the period before the efficient value of investment and production is attained.*[10]

The left column of Figure 2 illustrates the dynamic patterns of the optimal investment, production and tax payment for two levels of institutional quality: $C = 0.8$ and $C = 0$. With strong institutions $C = 0.8$, investment and production reach I^* earlier, relative to settings with weaker institutions $C = 0$. This

[8]Concentrating on the best equilibrium for the firm does not alter the characterization of the contract significantly. By doing so, we are selecting the most backloaded contract (Ray, 2002) In addition, for exposition purposes, we focus on a parameter range such that I^* is eventually reached with probability one. See the Appendix A for more details.

[9]More precisely, V_{t+1} increases in periods with a high price $p = 1$. When the price is low $p = 0$, there are no revenues to expropriate and the firm does not need to backload. In those periods, the government's value is constant $V_t = V_{t+1}$. See the Appendix A for more details.

[10]This proposition is akin to Proposition 1 in Thomas and Worrall (1994).

observation is generalized in the following Lemma:

Lemma 1. *The number of periods to achieve the efficient frontier in agreement A decreases with the quality of institutions C.*

Regarding tax payments, they start to be paid earlier with stronger institutions and their stationary levels are lower. In contrast, governments in countries with weaker institutions need to eventually receive higher rents to prevent expropriation.

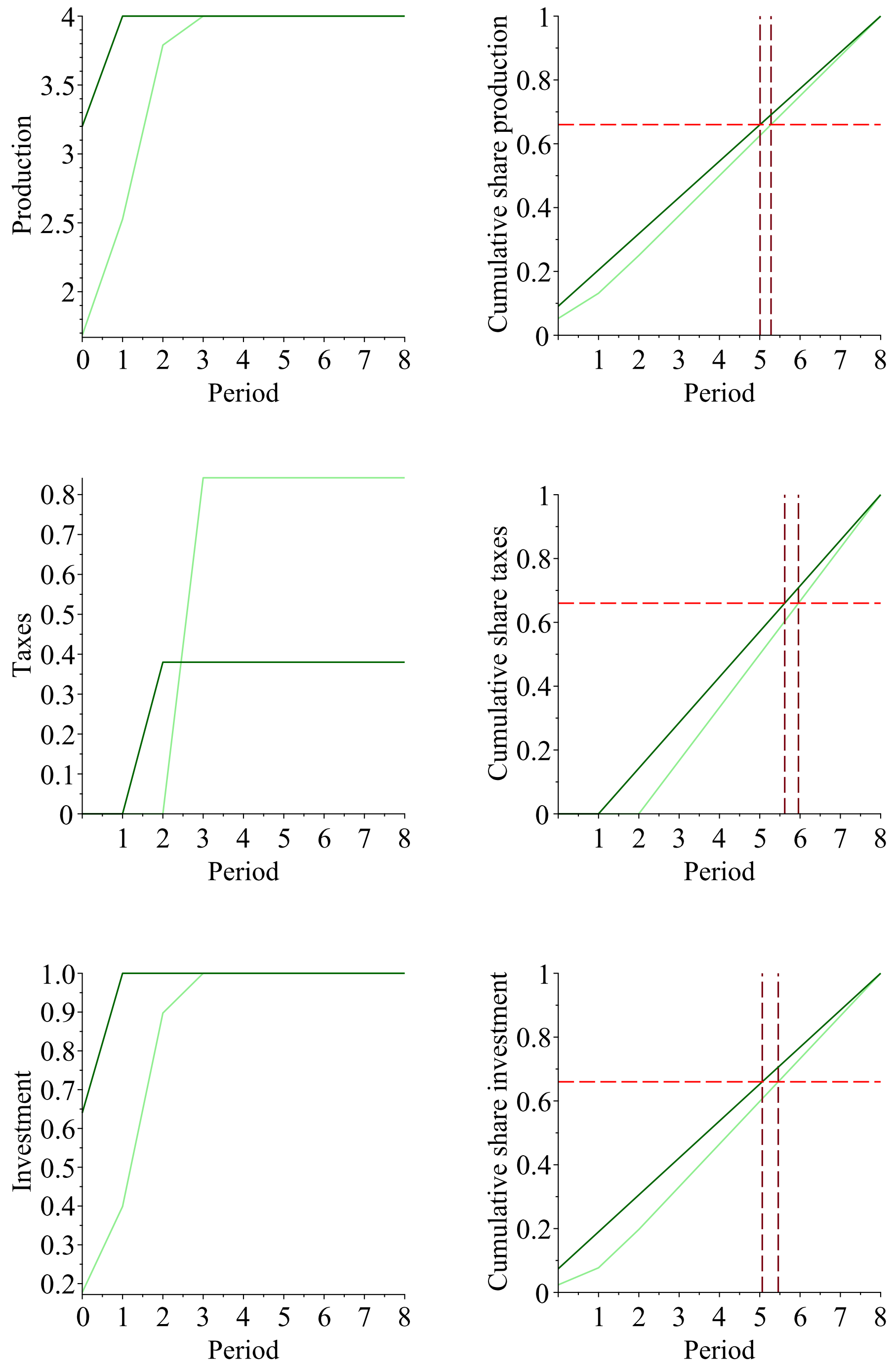
Empirically, the optimal levels of investment, production and tax payments greatly differ across fields for many reasons beyond the quality of institutions. These reasons include geological, climatic and technological constraints. This suggests that the comparison of an over-time evolution of the *levels* of investment, production and taxes - as in the left panel of Figure 2 - may be biased and misleading. To reduce field-level heterogeneity and focus on the dynamics of our variables of interest, we use a more tractable measure of backloading which captures how fast these flows accumulate over a fixed period of time. Let X_n be *Investment, Production or Taxes* in period n, N the number of periods over which the cumulative share (CS) of X_n is calculated and $s \in [0, 1]$ a chosen value for the CS. Our measure of backloading is then the number of periods $\bar{n} \in \{1, \ldots, N\}$ needed to reach the cumulative share s:

$$CS_{\bar{n}} = \frac{\sum_{n=1}^{\bar{n}} X_n}{\sum_{n=1}^{N} X_n} = s \tag{1}$$

Using this measure, the stream X_n under agreement $A1$ is *backloaded* relative to that under agreement $A2$ if it accumulates slower under $A1$ than under $A2$. Slower accumulation is measured as the larger number of periods needed to reach a given cumulative share s. The right column of Figure 2 illustrates how, under weak institutions, investment, production and taxes are backloaded, since it takes more periods (measured by the distance between the vertical lines) to reach 66% of the cumulative share indicated by the dashed horizontal line.[11] This relationship

[11] Alternatively, a delay in accumulation can be measured on the y-axis as a difference in the

Figure 2: Optimal agreement ($\delta = 0.8$ & $C \in \{0.8, 0\}$)



between institutions and backloading is proven in the following comparative statics

cumulative share of the stream X_n under two agreements reached by a given number of periods $\bar{n}$.

result:

Proposition 2. *Investment and production are more backloaded with weaker institutions. It takes longer to start paying taxes under weaker institutions.*[12]

This result allows us to form our first testable hypothesis:

Hypothesis 1: *Consider a threshold s for the cumulative share of production/investment. It is reached faster in countries with strong institutions compared to those with weak institutions. For tax payments, it can be reached faster or slower.*

Our main empirical tests uses the value $s = 0.66$ as depicted in Figure 2. We also test other values of s in the Online Appendix C.

The above discussion also offers an insight into the dynamics of backloading. As the relationship evolves, the government's future value of the relationship increases. This reduces the expropriation incentives at the later periods and, as a result, the need to backload (i.e. backloading vanishes with time). In particular, once the efficient I^* is reached, investment and associated production remains at this stationary level. For our empirical, cumulative share-based measure, any backloading is exhausted by period N as the cumulative share reaches 1 at that period independent of institutions. More generally, in the next Proposition, we show that the extent of (relative) backloading in shares between agreements with weaker and stronger institutions gradually decreases over time.

Proposition 3. *There exists a period $t < N$ after which the differences in investment and production backloading between weaker and stronger institutions monotonously tends to zero.*

This result gives rise to our second testable hypothesis:

Hypothesis 2: The differences in investment and production backloading between countries with strong and weak institutions vanish over time. For tax payments, the difference may or may not vanish.

[12] Once the efficient investment I^* has been reached, current taxes can be traded against future taxes in many different ways without affecting the efficient level of investment. Thus, tax payments under weak institutions may be more or less backloaded after I^* is reached.

3 Data and stylized facts

3.1 Data description

Oil and gas data. The micro-level data on oil & gas fields comes from Rystad Energy, an energy consultancy based in Norway. Its database contains current and historical data on physical, geological and financial features for the universe of oil & gas fields worldwide. Rystad collects the data from a wide range of sources, including company and government reports and expert interviews. In some cases, Rystad imputes observations. Asker, Collard-Wexler and De Loecker (2019) provide a very detailed description of the data construction process.[13] Our discussions with Rystad representatives and researchers working with this dataset suggest that Rystad provides the highest quality data available in the industry and that the information on the physical production volumes and tax payments at the field level are particularly accurate.

Our sample contains all the fields worldwide owned by at least one oil major. A field may be thought of as containing *at least* one production well and be operated by *at least* one firm in *at least* one country. The oil majors are BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Royal Dutch Shell and Total. Historically, these are the largest private firms in the industry. They have been active for a long time, and they own fields in many countries. Jointly, these two characteristics imply that we have sufficient spatial and time variation to capture dynamic patterns in long-term relationships. We restrict our analysis to those fields which began production between 1960 and 1999, and in order to measure the extent of backloading in the long run, we only use fields which have been in operation for at least 20 years.[14]

[13] There is a growing multifaceted literature using the Rystad database. Asker, Collard-Wexler and De Loecker (2019) is among the earliest and most prominent examples of this literature. They document the allocative inefficiencies generated by the OPEC (Organization of the Petroleum Exporting Countries) cartel, but they also offer perhaps one of the most detailed and precise descriptions of Rystad database content and methods. More recently, Bornstein, Krusell and Rebelo (2023) use the same data to construct a global model of the oil market.

[14] The quality of the data deteriorates when going back in time further than 1960. Also, we only use fields which have been in operation for at least 20 years since it is difficult to empirically capture backloading in less time due to the large, geologically-driven field-level heterogeneity in investment and production during the early years of a field's life (Adelman, 1962). Finally, note that our data consists of realized contracts (i.e. we do not observe ex-ante agreements).

We construct our backloading measure using the first 35 years of a field's life. Since we need profitable fields that can be taxed, we only use fields which generate a surplus within a period of 35 years. In total, this implies that we are dropping around 3% of the cumulative production generated by the oil majors over the full sample period. Finally, the stylized facts are based on the sample from 1974 onward, while we extend the sample back to 1960 for the causal analysis.

For all fields, we observe the year in which exploration rights have been acquired and the year in which production starts. We also observe the physical reserves, local climate conditions, type of commodity extracted (i.e. oil or gas), whether the field is located off- or onshore and the exact geographical location. Then, for every field, we have yearly data on the type of fiscal regime (i.e. concession, production sharing agreement (PSA) or service contract), ownership rights, physical production (in million barrels), different types of capital and operational expenditures, revenues, profits and different forms of taxes. All the financial flows are converted to millions of real 2018 USD. Online Appendix B provides a detailed description of all the variables.

The tax payment variable deserves a special mention. To construct it, we use information on tax payments under a variety of fiscal regimes. It captures the total amount of payments received by the government from a field including royalties, government oil profit (PSA equivalent to petroleum taxes), export duties, bonuses, income taxes and profit taxes. In the oil literature, this measure is known as the *government take*. To match the assumptions of the modeling setup regarding the absence of negative tax payments, we need to abstract from subsidies. We do this by considering two different measures: (1) royalties and profit taxes only, which do not contain any subsidies and, (2) all the tax payments, while setting the value of the income tax to zero in periods in which the reported government take is negative. This does not have a significant impact on our measure since the cumulative amount of subsidies received by the median field in our sample adds up to 2% of the total government take. For over 90% of all the observations in our sample, this share remained well below 10% (see Figure C.2).

Institutional measures. To differentiate countries by their institutional

Table 1: Descriptive statistics: fields starting operations in 1960-1999

	Strong		Weak		Mean comparison	
	mean	sd	mean	sd	diff	p-value
Field Lifetime, years	33	0.2	35	0.3	-2	0.00
Cum. Production, MMbbl	42	4.4	41	2.8	1	0.89
Cum. Real Revenue, MUSD	1671	202	1883	142	-212	0.42
Cum. Real Cost, MUSD	644	72	456	30	188	0.03
Cum. Real Taxes, MUSD	698	92	1060	84	-362	0.00
Cum. Real Profit, MUSD	328	42	366	39	- 38	0.52
Number of fields	1986		1508			
Countries	17		32			

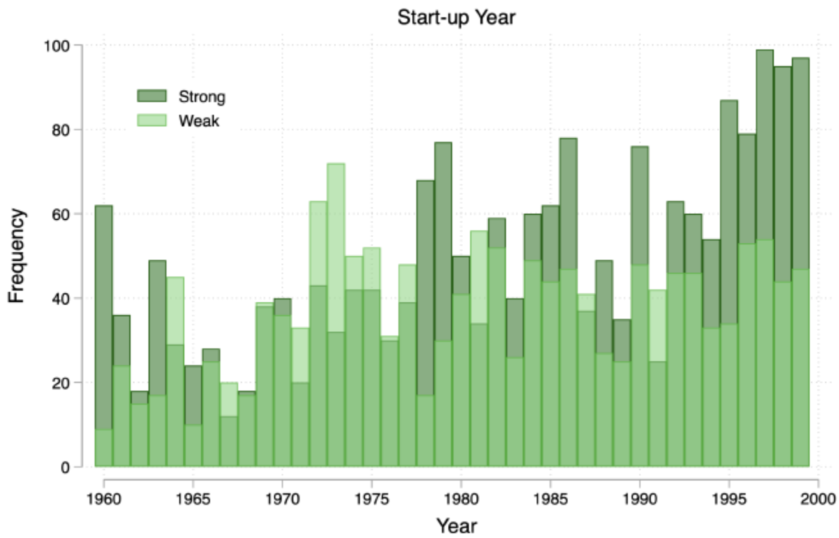
Note: Monetary measures are in real 2018 US dollars. The lifetime of the fields (first row) is not restricted to 35 years. The other measures are restricted to fields which are in operation for at least 20 years and are calculated for up to the first 35 years of fields' lifetime. Extending the other measures to the full lifetime of the fields does not qualitatively change the results. A two sided t-test is used to calculate the p-values.

quality, we rely on Polity IV. In particular, we use country-level annual information on executive constraints (XCONST), which measures the extent of institutional constraints on the decision-making powers of the chief executive, whether an individual or a collective executive.[15] To reduce the possibility that causality flows from oil wealth to institutions rather than the other way, we use the median score (above or below 5) received by a country from 1950 to 1975. In the empirical section, we extend the number of groups to three by splitting the countries with weak institutions into two groups: the weak (XCONST of 3-5) and the very weak (XCONST of 1-2). Alternatively, we also use OECD membership before 1970 and during the early 1970s as a measure of strong. Our results remain robust to these changes and are available upon request.

We present the descriptive statistics for our sample in Table 1 by distinguishing between countries with weak and strong institutions. Cumulative production and revenues do not differ significantly across groups of countries, while the average lifetime of a field is 2 years larger in countries with weak institutions relative to

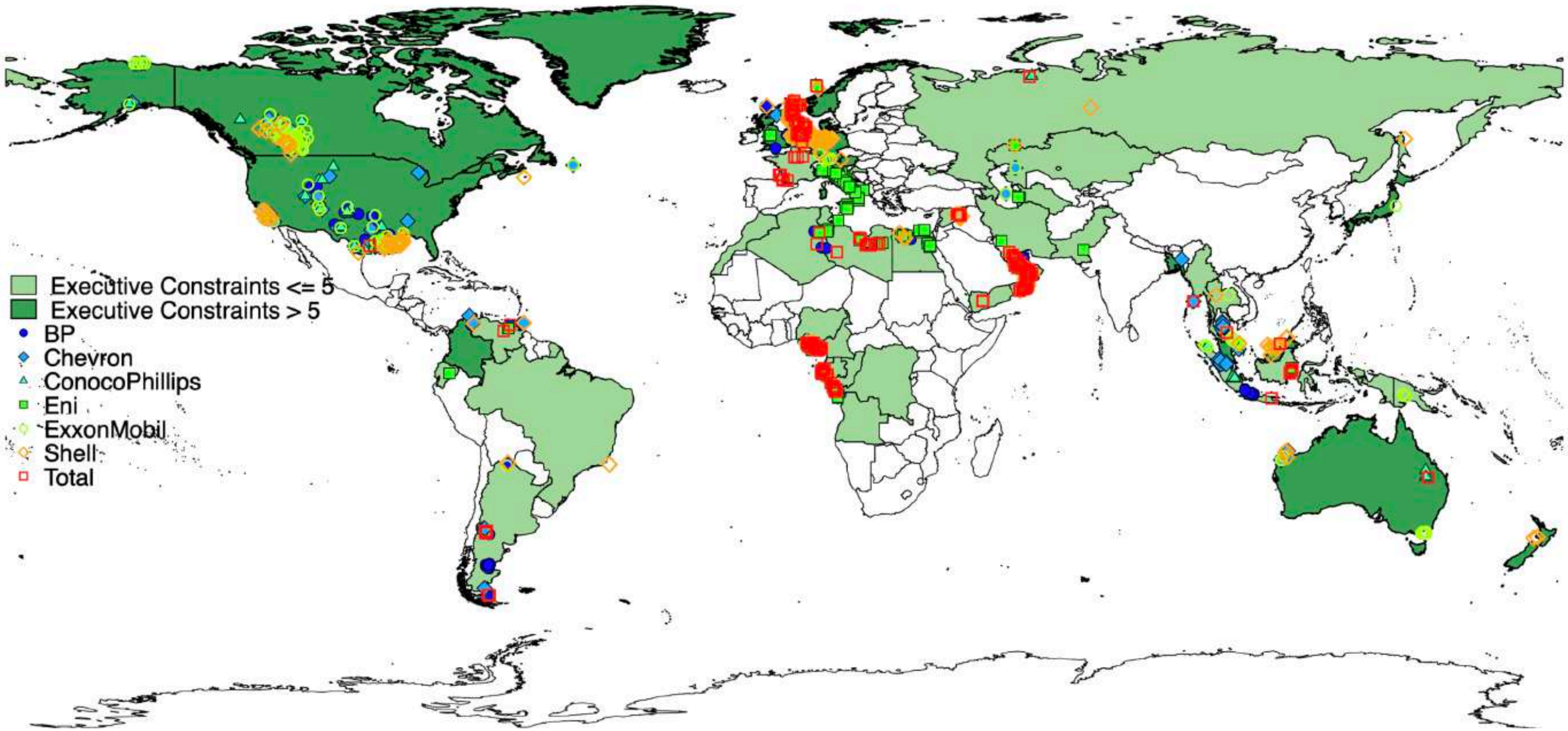
[15] The country-specific median of this measure for the period 1974-2007 is negatively and significantly correlated with the number of expropriations in the oil and gas sector. Data on expropriations is taken from Guriev, Kolotilin and Sonin (2011) and Stroebel and Van Benthem (2013).

Figure 3: Timing of the start of production



countries with strong institutions. This is in line with the presence of backloading in countries with weak institutions. Also, total cost of extraction per field is higher in developed countries, while the amount of taxes paid is lower. The former fact is well known and is typically attributed to the fact that the exploration of oil & gas has been taking place for much longer in developed countries, such that the easy-to-access fields have already been exhausted. On the other hand, the latter statement indicates that governments in developing countries are getting larger rents, which is consistent with the theory in section 2. Compensating higher taxes with lower extraction costs leaves the oil majors indifferent between investing in fields located in developing and developed countries, as the firms' profits do not differ significantly between groups of countries on average. Figure 3 shows that there is a balanced frequency of fields starting production by group of country. Between 1960 and 1999, on average, 40 fields per year started production in countries with weak institutions, while 50 fields per year started production in countries with strong institutions. Figure 4 presents the spatial distribution of fields covering the majority of oil & gas rich countries.

Figure 4: Spatial distribution of fields and institutional quality



Note: Longitude and latitude of individual fields is provided by Rystad. The executive constraint indicator is taken from PolityIV and we use the median from the period 1950 to 1975. The cut-off of 5 implies that roughly one third of the countries are defined as having strong institutions and roughly 50% of all the fields which started operation between 1960 and 2000 are located in countries with weak institutions.

3.2 Stylized facts on backloading

We use field level data to document the presence of backloading in the raw data. We construct our main dependent variable using: well CAPEX and production OPEX as a proxy for investment; physical production and the two alternative measures of tax payment, overall tax payment without subsidies and royalty & profit tax only. Our preferred variable is production because, in addition to its quality, it does not require any discounting over time. Our measure of backloading in (1) is the *number of years needed to reach a value s of the cumulative share of investment, production and tax payments over the life cycle of the field.* We construct the following measure for all the key variables with $X_{f,n}$ indicating the *real* values of investment, tax payments and physical production of field f in period n. Period n equals 1 in the year in which production starts, and we choose 35 years to be our baseline N. To control for investments potentially taking place prior to the start of production, we begin calculating the cumulative shares 5 years prior to beginning of production. Our backloading measure is $\bar{n}$, the number of periods required to reach a cumulative share $CS_{f,\bar{n}}$ equal to s over the lifetime N:

$$CS_{f,\bar{n}} = \frac{\sum_{n=-5}^{\bar{n}} X_{f,n}}{\sum_{n=-5}^{N} X_{f,n}} = s \tag{2}$$

Figure 5 depicts $CS_{f,\bar{n}}$ against $\bar{n}$ in countries with weak and strong institutions. Our main dependent variable in the empirical analysis, y_f, indicates the number of periods $\bar{n}$ which a field f needs to reach the threshold of $s = 66\%$ of cumulative share, and it is depicted by the two vertical red dashed lines (one per type of country).[16] For all the variables, oil majors need 1-3 years more in order to reach 66% in countries with weak institutions relative to countries with strong institutions. For our preferred measure, production, we extend the number of groups to three by splitting the countries with weak institutions into two groups: the weak (XCONST of 3-5) and the very weak (XCONST of 1-2) and illustrate the results in the middle right panel of Figure 5. The first order stochastic dominance

[16] Our results are robust to different choices of N and s. Please, see the Online Appendix C.

of the average CDF in countries with strong institutions relative to countries with weak institutions is consistent with the presence of backloading as predicted by the theory and which we emphasize here as a stylized empirical fact.

4 Identification and results

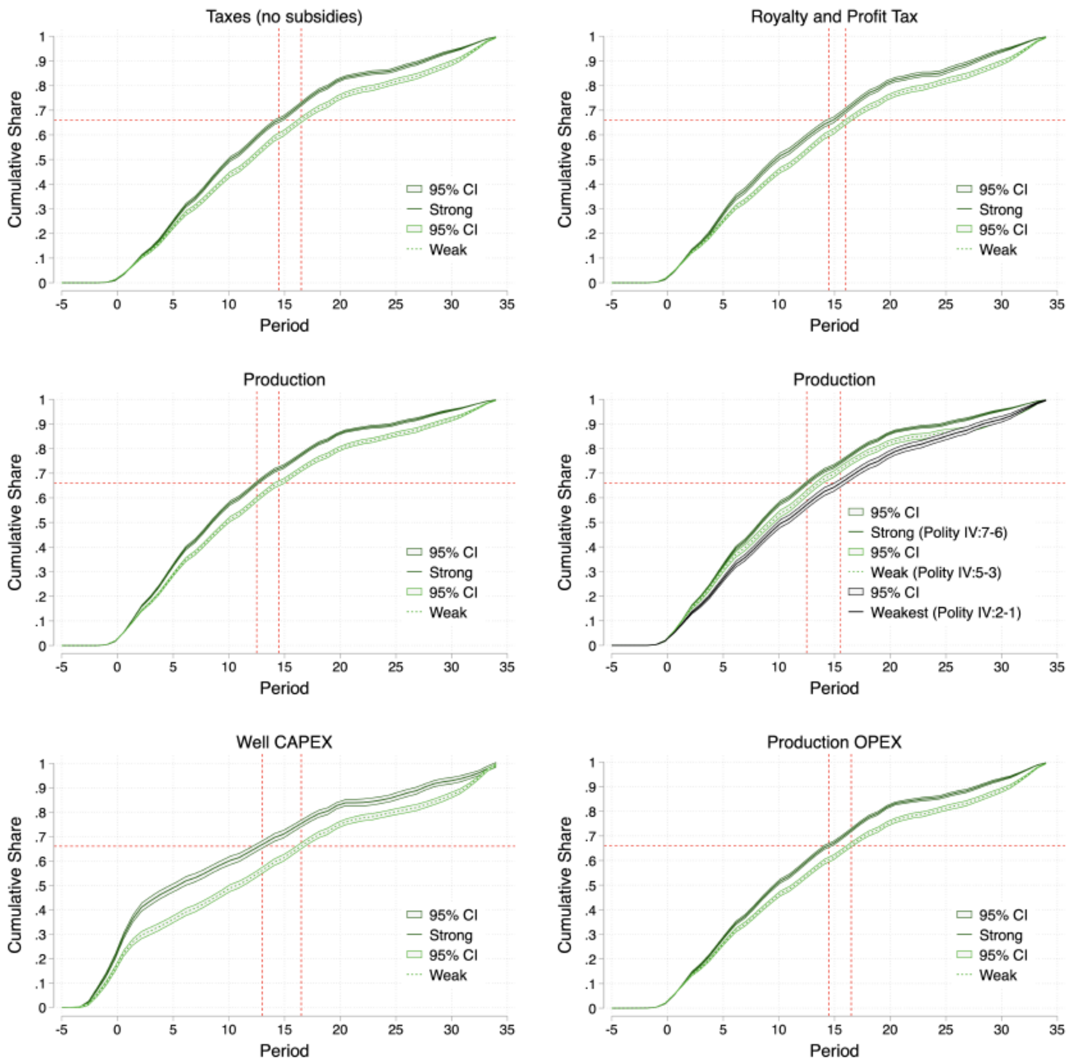
In this section, we present our main empirical results. First, motivated by the stylized facts presented in the previous section, we estimate the presence, and extent, of (relative) backloading in weak institution economies while controlling for a variety of observable field characteristics. Then, we proceed to give the backloading a causal interpretation. To do this, we exploit the global increase in the threat of expropriation brought by the reduction in the military contract enforcement to show that backloading in weak institutional environments emerges around the time when such enforcement subsides.[17] Finally, we document that the backloading disappears as the relationship matures.

4.1 Backloading with controls

We estimate differences in the timing of contracts in weak and strong institutional environments. While doing so, we account for a number of geological, geographical and other field characteristics to rule out the possibility that the stylized facts presented in Figure 5 are driven by observable field-level characteristics that may be correlated with the quality of institutions across countries. The richness of our dataset allows us to control for a set of geographical characteristics that includes the exact location, whether the field is onshore or offshore and the climatic conditions as well as a set of geological characteristics that include the size of the reservoir and the type of fossil fuel extracted. To capture some basic relationship characteristics, we also account for the firm operating the field and the type of the fiscal regime associated with the field. Finally, we account for the year in which

[17] In Online Appendix C, we provide additional robustness checks and discuss the influence of confounding factors, while in Online Appendix D, we use the case studies of four countries to explore cross-country heterogeneity in the timing and the intensity of contract backloading.

Figure 5: Years to reach 66% of cumulative flows in 35 years



Source: We use the Epanechnikov kernel with a bandwidth of 0.5. We plot the cumulative production, investment, and tax payments over the 35 year life span of the field. As discussed in the text, we use only fields which have been in operation for at least 20 years. Countries are grouped according to their executive constraints as measured by Polity IV.

production started and the lifetime of the field, i.e. the number of years for which we observe the fields since the beginning of production. Conditional on these controls, we use (2) to estimate the following specification with y_f, indicating the field specific number of years $\bar{n}$ needed to reach 66 % of the CS of the stream $X_{f,n}$:

$$y_f = \beta \text{Weak}_{c(f)} + \Omega'_f \gamma + \varepsilon_f \tag{3}$$

$Weak_{c(f)}$ is a dummy variable which is equal to 1 if the field is located in a country with weak institutions. Our coefficient of interest β provides an estimate for the difference in the number of years needed to reach 66% of cumulative production, investment and tax payments between countries with strong and weak institutions. Ω_f is a vector of field specific characteristics for which we control. The standard errors are clustered by country, start-up year and the lifetime of the field. The estimates of β are presented in Table 2. To assess the effect of the controls, we present the results both with a limited number of controls (the year in which production starts and the field's lifetime) and with the full set of controls, in columns with odd and even numbers, respectively. Overall, the results in Table 2 are robust to the inclusion of all controls and suggest that it takes up to 2 more years in countries with weak institutions to reach the same level of cumulative investment, production and tax payments as in countries with strong institutions.

Our results are robust to different measures of institutional quality, alternative thresholds of cumulative share s and different cutoffs of the fields' lifetimes N. Tables C.1 and C.2 in Appendix C.3 summarize the results for alternative choices with all the controls in the former and with a limited set of controls in the latter.

4.2 Backloading and the increased threat of expropriation

While the above results with controls are encouraging, they could be driven by other factors present in countries with weak institutions that are not related to the government's ability to expropriate, such as poor infrastructure or corruption. In this section, we establish a causal link between the enforcement of contracts and backloading. To do this, we exploit the historical period when the state's ability to

TABLE 2: Years to reach 66% of cumulative flows in 35 years

	(1) Taxes	(2) Taxes	(3) R&P	(4) R&P	(5) Production	(6) Production	(7) CAPEX	(8) CAPEX	(9) OPEX	(10) OPEX
Weak (Polity IV)	1.341**	1.725**	1.577*	1.892**	1.528**	2.071***	4.418**	1.977**	1.505*	1.244*
	(0.625)	(0.677)	(0.890)	(0.834)	(0.592)	(0.504)	(1.825)	(0.891)	(0.797)	(0.705)
N	2620	2616	2046	2042	2620	2616	1463	1461	2620	2616
Countries	47	47	44	44	47	47	46	46	47	47
R-sq	0.27	0.33	0.25	0.32	0.30	0.37	0.19	0.49	0.21	0.27
Start-Up Year	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lifetime of the Field	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Location (Long. and Lat.)	N	Y	N	Y	N	Y	N	Y	N	Y
Onshore vs. Offshore	N	Y	N	Y	N	Y	N	Y	N	Y
Climatic Conditions	N	Y	N	Y	N	Y	N	Y	N	Y
Fossil Fuel Type	N	Y	N	Y	N	Y	N	Y	N	Y
Reservoir Size (logged)	N	Y	N	Y	N	Y	N	Y	N	Y
Fiscal Regime	N	Y	N	Y	N	Y	N	Y	N	Y
Firm	N	Y	N	Y	N	Y	N	Y	N	Y

Notes: Year of Production Start-Up FE and the lifetime of the field are included in all regressions. In columns with even numbers, we also control for a large number of field-specific observable characteristics. The left-hand side variable is capturing the number of years until 66% of cumulative level of OPEX, well CAPEX, production and tax payments in 35 years is reached. SE in parentheses are clustered by country, start-up year and lifetime of the field. * stands for statistical significance at the 10%, ** at the 5% and *** at the 1% percent level.

expropriate in countries with weak institutions increased (as the external enforcement of contracts recedes). Comparing the contracts between these countries and those with strong institutions, we show that backloading in the former emerges at this point.

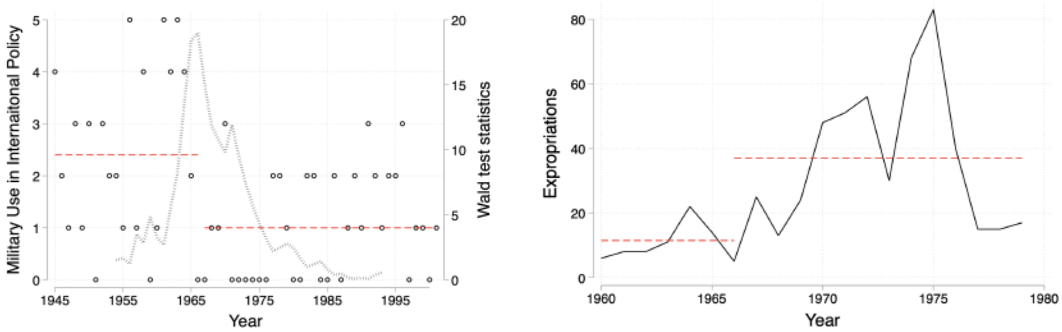
Traditionally, firms from developed countries have been backed by their countries of origin in their expansion into the developing world (Yergin, 2011). This has been particularly the case in the oil industry, where the US, the UK and France have used their military to ensure that contracts were not renegotiated. One of the most infamous example followed the Iranian attempt to nationalize BP's oil fields in the early 1950s. It resulted in a coup d'etat and the replacement of an initially democratic government with a monarchy until the Iranian revolution in 1979.[18] Scared by the Iranian example, only few oil rich economies attempted the renegotiation of oil deals with the big oil firms throughout the next decade.

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

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

[18]See footnote 2 for more details.

Figure 6: Change in military interventions and expropriations



Notes: Data on military interventions is taken from Sullivan and Koch (2009). The left graph depicts the average number of military interventions by the US, UK and France between 1945 and 2000. In the background, we document the Wald Test for the endogenous structural break choice. On the right graph we plot the number of expropriations in all industries (Kobrin, 1984). The dashed horizontal lines in both figures represent the averages for the periods before and after 1966 as suggested by the Wald test.

where K is the cost imposed on the country by military intervention inflicted by the firm's country of origin. For any C, if K is large enough, the constraint (SE') does not bind. In other words, an external threat of a military intervention acts as a substitute for strong rule of law in enforcing agreements. Since the agreement is "military-enforced", it does not need to be backloaded.

However, as time passed, the use of military interventions lost momentum. Indeed, based on the data from Sullivan and Koch (2009), we document a pronounced decrease in the use of politically motivated military interventions in the second half of the 1960s, as illustrated by Figure 6. The Wald test statistic points to a single structural break in 1966, when the average number of military interventions dropped from around 2.4 to 1 per year. The right part of the Figure shows the increased number of expropriations from around 15 to 40 per year.

The reduction in the use of military interventions was driven by both external and internal factors. First, the post-war decolonization wave brought about a change in the international economic system, bringing countries' sovereignty over natural resources into focus. While these attempts were not immediately successful, they eventually changed worldviews on the right of states over their natural resources. The resulting international pressure undermined the use of military interventions by the Western world.[19] This change was signified by the UN general assembly granting resource rich economies permanent sovereignty over their natural resources and effectively legitimizing expropriations by 1974.[20]

Second, the use of military interventions also faced increasing domestic resistance in the counties relying on such practices. This was particularly apparent for the US, which at the time was involved in the Vietnam War. By 1964, over 20000 US soldiers were deployed to Vietnam. As a response, the US government started facing a growing number of anti-war protests (see Figure C.1 in the online Appendix), which triggered political change and resulted in Lyndon Johnson being replaced by Richard Nixon as US president in 1968.[21] By 1973, increased dissatisfaction with the politically motivated use of military power resulted in a complete US withdrawal from Vietnam.

In the oil & gas sector, the changing paradigm can be illustrated by the creation and evolution of OPEC.[22] Created in 1960 with the intention of returning resource sovereignty to its owners, OPEC had very limited influence until the late 1960s.[23] But in 1968, OPEC released the Declaratory Statement of Petroleum Policy in Member Countries, which emphasized the right of every nation to have complete sovereignty over their natural resources (Dietrich, 2017). In the years following the declaration, several expropriations by OPEC members, such as in Libya and Algeria, were tolerated by the Western world. This was in clear contrast to the reactions by the same countries throughout the 1950s. Eventually, in 1973, the unwillingness of the oil consumer countries to use their military power to pursue their energy security goals was unambiguously revealed in the events surrounding the Yom Kippur War. The US and a few allies decided to support Israel during the war, to which the Arab members of OPEC responded by imposing a successful

[19] A good illustration is the gradual retreat of Britain's military presence in the Middle East, beginning with the 1967 announcement of complete withdrawal of British forces deployed *"East of Suez"*, including from the Persian Gulf, by the end of 1971.

[20] The UN resolution 3201 (S-VI) explicitly established a New International Economic Order.

[21] The Vietnam War was the primary reason for the steep decline of President Johnson's popularity.

[22] OPEC was created by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. By 1971 this group of countries was joined by Algeria, Indonesia, Libya, Nigeria, Qatar and the UAE.

[23] In particular, the attempt of its Arab members to use "oil as a weapon" and initiate an oil embargo following the 1967 Six-Day War is largely considered a failure.

oil embargo against these countries. But OPEC's costly cuts in oil supply did not trigger any military response from the US or its allies (Yergin, 2011).

In the framework of our model, this implies that after 1973, K in the constraint (SE') is set to zero, and the agreements between oil producing countries and oil companies need to be self-enforcing and hence backloaded in countries with weak institutions. This structural change and its consequences for the threat of expropriation are also summarized by Kobrin (1984). *"[T]he success of Third World countries in pressing for agreement on the issue of National Sovereignty of Natural Resources at the U. N., the ability of Vietnam to withstand US military action, and OPEC's achievement of control over pricing and participation, resulted in a climate that may have exacerbated tendencies toward direct and dramatic action such as expropriation"*. Indeed, as shown in the right panel of Figure 6, there had been an escalating number of expropriations since 1967. Oil companies had to adjust to this new reality by devising self-enforcing agreements.

To test this hypothesis, we transform equation (3) into a Difference-in-Differences specification and estimate the following specification for the period 1960 to 1980:

$$y_f = \sum_{j=1960, j\neq 1966}^{1980} \beta_j \times \text{Year}_{j(f)} \times \text{Weak}_{c(f)} + \text{Weak}_{c(f)} + \text{Year}_{j(f)} + \Omega_f' \gamma + \varepsilon_f \quad (4)$$

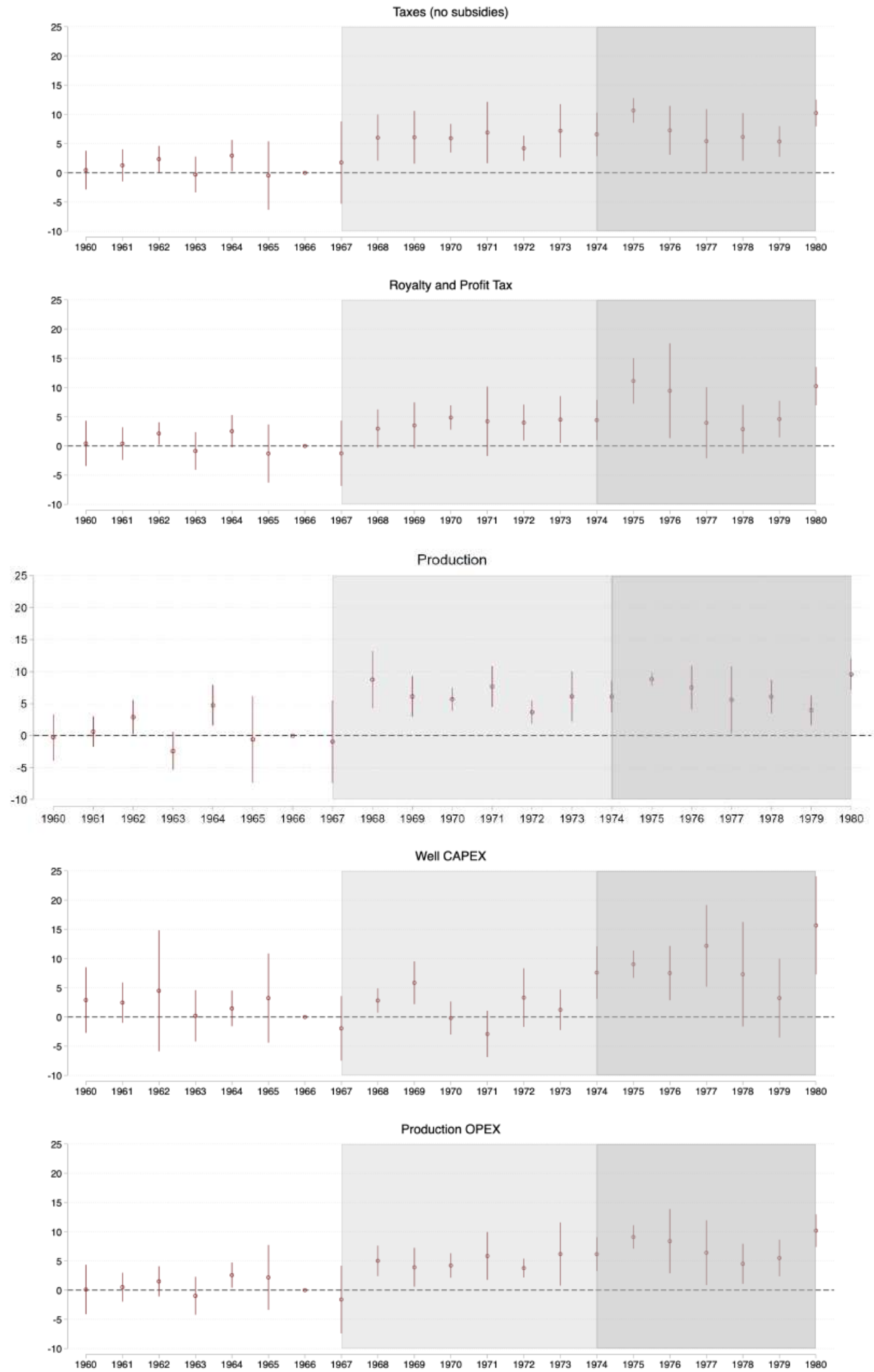
As in equation (3), y_f captures the field-specific number of years $\bar{n}$ necessary to reach 66% of the cumulative flows of investment, production and tax payments. $Weak_{c(f)}$ is a dummy variable which is equal to 1 if the field is located in a country which is categorized as having weak institutions. We interact $Weak_{c(f)}$ with a dummy, which is equal to 1 if field f started production in year j. Our coefficient of interest, β_j, measures the difference in the number of years needed to reach 66% of production, investment and tax payments in countries with weak institutions relative to countries with strong institutions between 1960 and 1980. Motivated by the results in Figure 6, we choose 1966 as our baseline. We carry our analysis forward until 1980 because of the absence of Investor-State Dispute Settlements in that period. International arbitration can serve as a substitute for weak local institutions, decreasing the need for backloading, and the first settlement case in the energy sector took place shortly after 1980 (Delpeuch, 2022). As before, Ω_f is a vector of field-specific characteristics for which we control, and the standard errors are clustered by country, start-up year and the lifetime of the field. If our hypothesis is correct, the estimated β_j's should be around zero prior to 1966. This is because contracts are either enforced by courts in countries with strong institutions or military enforced in countries with weak institutions. The β_j's should then turn positive after 1966 since military enforcement is reduced.

The results are presented in Figure 7.[24] All estimates are conditional on country group dummies, the year in which production starts, the lifetime of a field, the exact location, the climatic conditions, the size of the reservoir, the type of fossil fuel and the operating firm. The identification assumption is that, conditional on the control variables, the evolution of outcomes in countries with weak institutions would have followed a similar path as the outcomes in countries with strong institutions, had the military enforcement of contracts continued. The results are consistent across measures and suggest that the number of years necessary to reach 66% of cumulative investment, production and tax payments increase in countries with weak institutions by approximately 5 years relative to the control group from 1968 onward. The 5-year delay is approximately 3 times larger than our results from the cross-sectional estimates in Table 2. We discuss this difference in greater detail in section 4.3 but note that the increased threat of expropriation resulted in the resetting of many relationships. Hence, the 5-year delay captures the extent of backloading at the beginning of the relationship, which we expect to vanish as the relationship matures (see Hypothesis 2).

Figure 7 provides evidence for the appearance of backloading on the field level, that is, on the intensive margin. In Figure 8, we confirm that this pattern translates to the extensive margin. In countries with weak institutions, the cumulative number of acquired awards, which are necessary to develop and start production, decreased relative to countries with strong institutions while being on the same trend until 1966. Similarly, the number of years needed to start production after

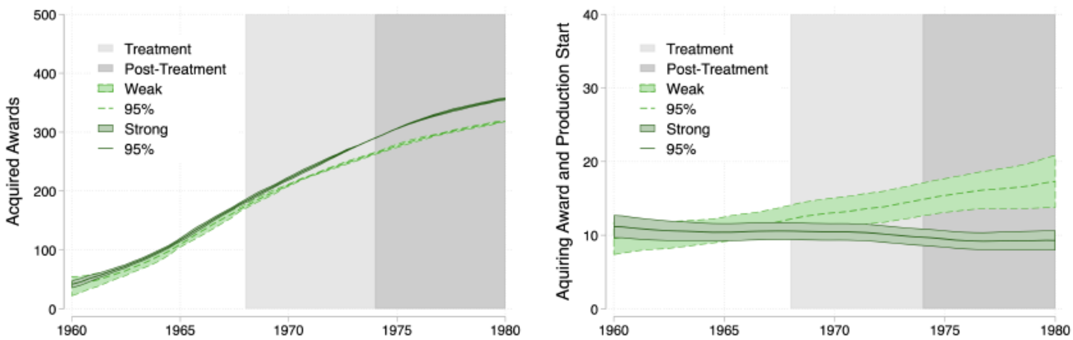
[24] In our preferred sample, we exclude countries which had received independence from colonizers after 1966 (Angola, Qatar, UAE, Yemen, Brunei and Papua New Guinea) but the results are robust to their inclusion.

Figure 7: Increase in the threat of expropriation



Notes: The outcome variable is the years to reach 66% of investment, production and tax payments over 35 years. Year of start up, country group FE and the field lifetime, location, climatic conditions, the size of the reservoir, the type of fossil fuel and the operating firm are included in all regressions. The shaded area marks the period of transition (1967-1973) and the period after 1974. The plotted interaction terms are on the year-level and the sample is limited to the period between 1960 and 1980, with 1966 being the baseline. SE are clustered by country, Start-up year and the lifetime of the field. We plot the 95% Confidence Intervals.

Figure 8: Extensive Margin



Notes: We use the Epanechnikov kernel with a bandwidth of 2. In the left graph we plot the cumulative number for awards acquired in countries with weak and strong institutions. In the right graph we plot the distance in years between the year in which an Award is acquired and the year in which production starts.

an award is acquired increased in countries with weak institutions relative to the control group in the early 1970s, while being on the same level before 1966.

In Appendix C, we provide additional empirical evidence and discuss the influence of unobservable confounding factors in support of the causal interpretation of the results in Figure 7. First, we look for evidence of contract renegotiation after production starts (see C.4). Comparing the production dynamics across countries of fields which start production around the year of the structural break, we do not find any evidence for ex-post renegotiation of contracts. The production dynamics seem to be, at least partly, predetermined by the year in which production starts. However, since we only observe the realized contracts and not the ex-ante contractual terms, our dataset does not allow us to conclusively answer this question. Second, the results presented in Figure 7 are robust to a variety of changes in the specification (see C.5). In particular, the results are robust to dropping observable field-level characteristics as controls (see Figure C.4) and to the inclusion of country fixed effects (see Figure C.5). The results are robust to classifying countries as having weak institutions based on their OECD membership (see Figure C.6) and to the exclusion of OPEC member countries which joined OPEC before 1966 (see Figure C.7). In Figure C.8, we also show that the move to offshore drilling and the increased use of PSA, which represent "bad controls"

(Angrist and Pischke, 2014),[25] since they could be used strategically by firms to reduce the risk of expropriations, did not develop differently in countries with weak and strong institutions during the transition. In Figure C.9, we document that operational and capital expenditures have been increasing in countries with strong and weak institutions alike, implying that the reallocation of capital to countries with strong institutions did not result in an increased capital scarcity in countries with weak institutions. Section C.6 discusses the change in a country's borrowing costs and in the government's bargaining power vis-a-vis the firms, which presumably went up for countries with weak institutions during this time but remained unobserved. We also discuss the role of multilateral enforcement (Levin, 2002) and corruption (Troya-Martinez and Wren-Lewis, Forthcoming) in the relationship between governments and firms. In our discussions on all these points we conclude that, if these forces operated in the background and biased our estimates, that the bias should be negative such that our estimates reflect a lower-bound. Finally, Appendix D presents four case studies from different parts of the world, including Argentina, Indonesia, Libya and Nigeria. They allow us to explore in detail how the increased threat of expropriation played out in the context of different country settings. Jointly, these case studies suggest that strong political relationships between the host and home countries of foreign investments as well as contract designs which allow the host country to keep a share of the property rights reduce the need for backloading. On the other hand, nationalistic political movements, a well functioning NOC which makes expropriation feasible as well as contract negotiations and expropriations (perceived or realized) increase the need for backloading.

Finally, two other theories predict contract backloading. First, backloading may arise in anonymous markets where relationships start anew after an opportunistic action has taken place and this opportunistic behavior is unobserved by new partners. In such a setting, backloading emerges as a way to make switching to a new relationship more costly so that there are less incentives to behave

[25] Variables that are themselves affected by the increased threat of expropriation (outcome variables) by affecting firms' choices.

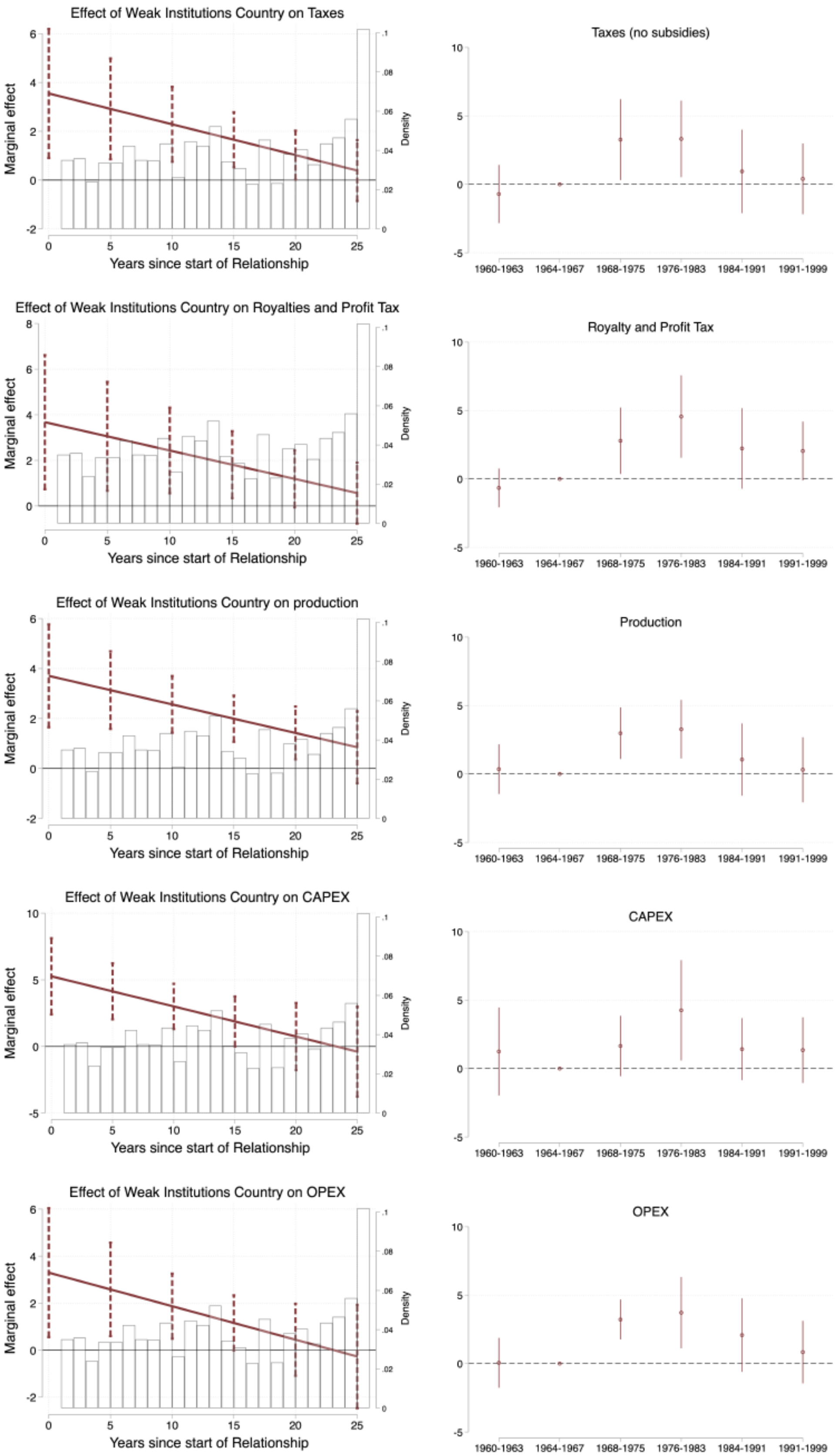
opportunistically (see Kranton (1996)). Unlike in this setting, expropriations are public information in the oil & gas industry. Second, backloading also arises in environments where there is asymmetric information about whether a player is opportunistic or not, as in Ghosh and Ray (1996). If the government can be opportunistic (i.e. always expropriates) or not, the firm starts the relationship small to use this first experimental period to screen out the government type. After that, opportunistic relationships terminate while non-opportunistic ones move to a fully cooperative level. One could imagine that the reduction in military contract enforcement created a situation in which the "type" of government started mattering in countries with weak institutions. But in the oil & gas industry, this type of screening has been documented to take place during the exploration phase which precedes production (Cust and Harding, 2020). Once the exploration is finalized and productions starts, relationships are long-lasting in our dataset. Moreover, according to this theory, once the type of government has been revealed as one who never expropriates, the firm has no reason to give rents to the government. Instead, Table C.3 shows that the government's rents increase over time, which is consistent with predictions of the model in section 2.

4.3 Long run dynamics

The model of section 2 shows how investment, production and tax payments eventually reach the efficient level and backloading vanishes as stated in Hypothesis 2. In this section, we test this prediction.

A relationship between the government and the firm starts in the year in which a firm is awarded a license for extraction for the first time in a particular country. For older relationships, we reset them to zero in 1973, due to the increase threat of expropriation documented above. Treating the number of years since the beginning of a relationship as the relationship duration, we can evaluate how the number of years which are necessary to reach a certain cumulative threshold in investment, production and tax payments changes over the lifetime of the relationship. As before, we differentiate between countries with weak and strong

Figure 9: Long-run dynamics



Notes: The left-hand side variable is the number of years until 66% of CAPEX, production and tax payments over 35 years is reached. The full set of controls (as in the even columns of Table 2) is included in all results. The left column documents the estimated marginal effect from equation (5). The right column presents the results from estimating a specification which is akin to (4), but the interaction terms are aggregated in 5-year bins, the sample is extended to 1999 and the baseline is 1964-1967. The SE are clustered by country, start-up year and lifetime of the fields. We plot the 95% confidence interval.

institutions by expanding our specification in equation (3) and interacting the $\text{Weak}_{c(f)}$ country dummy with the number of years which captures the duration, d, of the $\text{Relationship}_{d(f)}$ in the year in which production of field f starts:

$$y_f = \beta \text{Weak}_{c(f)} + \alpha \text{Relationship}_{d(f)} + \gamma \text{Weak}_{c(f)} \times \text{Relationship}_{d(f)} + \Omega'_f \gamma + \varepsilon_f \quad (5)$$

As before, our unit of observation is an individual field. y_f captures the number of years needed to reach 66 % of the cumulative flow of investment, production and tax payments. Ω_f is a vector of field-specific characteristics for which we control, and the standard errors are clustered by country, start-up year and field lifetime. We are interested in the marginal effects ($\beta + \gamma \text{Relationship}_{d(f)}$) which are presented in the left column of Figure 9. All variables of interest exhibit the same pattern. In the first years of the relationship, the time to reach the 66% threshold in countries with weak institutions is 4 to 5 years above the number of years needed to reach the same threshold in countries with strong institutions. Note that these estimates are close to the estimates presented in Figure 7 as expected. As the relationship matures, however, the extent of backloading diminishes. On average, the level of backloading does not differ significantly between countries with strong and weak institutions approximately 20 to 25 years after the relationship starts.

To evaluate how the increased maturity of contracts affects the level of backloading on the global level in the long run, we slightly adjust and re-estimate our specification in equation (4). In particular, we extend the sample to cover the period 1960-1999, and for the sake of a simpler illustration, we aggregate the time fixed effects of the interaction terms to 8-years bins. The results in the right column of Figure 9 suggest that that the initially observed backloading on the global level also decreases in the long run, as we would expect.

5 Conclusion

Our dataset of oil & gas fields allows us to carefully study relational contracting between governments and the oil & gas majors across a large number of resource rich economies, with weak and strong institutions, and over an extensive period of time. We show that since the early 1970s, investment, production and tax payments have been delayed in countries with weak institutions relative to countries with strong institutions. Exploiting a historical reduction in contract enforcement by military means, we show that physical and financial flows in the oil and gas industry became relatively more backloaded in countries with weak institutions. We also show that the backloading disappears as the relationship matures. These findings are consistent with a large body of theory, and to the best of our knowledge, we are the first to document such contract dynamics empirically.

While the oil & gas sector is particularly well suited for studying self-enforcing contracts, there are many industries, other than resource extracting ones, to which our insights apply. For instance, Kobrin (1980, 1984) documents that firms in manufacturing and finance represented up to 40% of all the expropriated firms during the expropriation wave in the early 1970s. He argues that food and beverages, textile and construction material are particularly vulnerable to expropriations since they do not depend on advanced technologies to be operated and are typically self-sufficient with limited dependence on global supply chains. Understanding how changes in investment, production and the payment of taxes adjust to changes in the expropriation threat is very important since they have a direct and non-negligible effect on the gains from global trade and on the countries' economic development more generally (Findlay and O'Rourke, 2009).

Going further, a careful analysis of new datasets on international contracts between governments and firms as well as the use of alternative identification strategies to shed light on the causal link between international investments and the ability to enforce or self-sustain international contracts would be of great value. More precisely, backloading is just one specific dimension in which contracts between firms and governments may adjust to deal with the threat of expropriation. Are there other mechanisms? If yes, it is important to understand how such mechanisms may affect and interact with the extent of backloading. For instance, our case study of Indonesia suggests that the use of PSA may have decreased the country's returns from expropriation, creating a downward pressure on observed backloading. Alternatively, political proximity between the home countries of the investing firm and the host countries seem to have contributed greatly to the drop in backloading, as we document for Argentina. However, studying these mechanisms in detail is beyond the scope of the paper, and much more careful studies are needed to understand them. In this regard, future research could study these channels by exploring the introduction of new formats of contractual agreements for the former or exploiting changes to geopolitical relationships for the latter.

Our identification strategy exploits an increase in the threat of expropriations. We pin-down the time frame for this increase using military interventions. During this time, there were other factors that contributed to the increase in the expropriation threat such as the simultaneous creations of NOCs and the increase in the price of oil. Theoretically, both of these can contribute to an increase in backloading. Our analysis does not allow us to differentiate between the individual channels. This opens the door to future research, which could focus on differentiating between these mechanisms. Finally, our data set only allows us to observe realized investment, production and tax payments. Having access to the written contracts which are agreed upon ex-ante and being able to compare them to their realization ex-post, would certainly allow for many further insights about how international contracts react to changes in the global institutional environment.

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APPENDIX

A. PROOFS OF SECTION 2

Proof of Proposition 1

Let U and V be the discounted values of the firm and the government, respectively. We focus on the Subgame Perfect Equilibrium (SPE) that maximizes the firm's profits at the start of the game. Denote T_p the taxes paid by the firm and V_p the government's continuation value after price p is realized. The firm solves:

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

subject to the following set of constraints:
– the government's promise-keeping equation

$$V = \mathbb{E}[T_p + \delta V_p], \tag{PK}$$

– the government's self-enforcing constraint

$$\delta V_p + T_p \geq (1-C)r(I,p) + CT_p, \tag{SE}$$

– the limited liability constraint

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

– the firm's participation constraint

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

The government's participation constraint and the firm's self-enforcing constraint never bind and are omitted.[26]

To simplify the problem, note that when $p = 0$, (SE) is slack since $T_0 = r(I, 0) = 0$ and there are no profits to be expropriated, and (PC) is slack since $V_0 = V$. When $p = 1$, the right hand side of (LL) cannot bind, otherwise the firm incurs losses. So, using (PK), (LL) is transformed into

$$T_1 = 2V - \delta V_0 - \delta V_1 \geq 0. \tag{LL'}$$

Let $\lambda, \nu, \mu \geq 0$ be the Lagrange multipliers for (SE) and (PC) when $p = 1$ and (LL'), respectively. Then the FOCs for the above problem are

$$I = (1 - 2\lambda(1 - C))^2, \tag{6}$$

$$U'(V_0) = -1 + 2\lambda(1 - C) + 2\mu, \tag{7}$$

$$U'(V_1) = \frac{-1 - 2\lambda C + 2\mu}{1 + 2\frac{\nu}{\delta}}. \tag{8}$$

The envelope theorem applied to the problem above give us:

$$U'(V) = -1 + 2\lambda(1 - C) + 2\mu = U'(V_0). \tag{9}$$

Thus, $-1 \leq U'(V) \leq 0$ for all relevant V, where the latter inequality follows from Pareto-efficiency of the frontier.

In what follows we show that the Pareto frontier of the above problem consists of two parts: in the first-best part, FB, the self-enforcing constraint (SE) does not bind and $U(V)$ is linear. In the second-best part, SB, it binds, and $U(V)$ is a (decreasing) piece-wise quadratic function, achieving the maximum at $V = V_{\min}$. We assume that FB is non-empty, focusing on the case that parallels Case 1 in Thomas and Worrall (1994).[27] Then the Pareto optimal path maximizing firm's profit starts in this $V_{\min}$ and looks as follows: along the SB as $p = 1$, firm value V and investment I increase exponentially at the rates $1/\beta$ and $1/\beta^2$, respectively, where $\beta = \delta/(2 - \delta)$, and payments to the government $T_1 = 0$ (at $p = 0$ they stay constant and $T_0 = 0$). This continues until the k-th high-price period when the next step for V, V/β no longer belongs to the SB. Then there are two possible developments: Case 1.1 has the same pattern as in previous $k - 1$ periods, while in Case 1.2 V_1 may be bounded by the firm participation constraint, $V_1 = \min(V/\beta, V^{\#})$ where $V^{\#}$ is the maximum possible value $V^{\#} = 1/(1 - \delta)$. Then the investment may grow at a decreased rate and some positive taxes may occur. As of period $k + 1$ FB is reached, the investment stabilizes at its maximal, first-best optimal level $I = 1$ and remains constant forever. However, the evolution of T_1 and V_1 is not uniquely defined; since the (SE) constraint no longer binds,

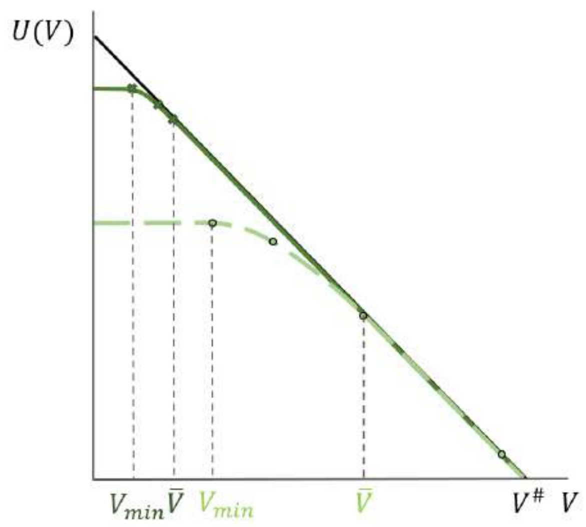
[26] The former follows from (LL). The latter is due to the assumption that, if the firm does not invest the agreed amount, the government expropriates the firm unless the courts uphold the initial contract with probability C. In either case, the relationship is terminated following a deviation. Thus, the best deviation is not to invest. The resulting self-enforcing constraint is:

$$-I + \mathbb{E}\left[r(I;p) - T_p + \delta U(V_p)\right] \geq C(-I + \mathbb{E}\left[r(I;p) - T_p\right])$$

which never binds, since the firm outside option is zero.

[27] This requires that $\delta < \dfrac{2 - 2C}{3 - 2C}$. For the case where the FB is empty, please see Case 2 in Thomas and Worrall (1994).

Figure A.1: Value function ($\delta = 0.8$ & $C \in \{1, 0.8, 0\}$)



today's T can be traded against tomorrow's value of V_1. As a result, there are many possible paths for V_1 and T_1.[28]

The above dynamics is illustrated in Figure A.1. For the reference, black solid line represents the Pareto efficient frontier with perfect institutions $C = 1$. Any point on the frontier constitutes a stationary contract, and the exact location depends on the bargaining power of the government. In particular, the agreement that maximizes the firm's utility gives the government $V = 0$. With weaker institutions, (SE) binds, which makes the upper part of the efficient frontier unattainable, as low V triggers expropriation. In this case firm underinvests and the Pareto frontier lies underneath the black solid line until V is high enough to prevent expropriation. The dynamics consistent with the maximization of the firm's profits for stronger ($C = 0.8$) and weaker ($C = 0$) institutions are depicted by the dark green and light green lines, respectively. The crosses and dots on the feasible frontier indicate the path of the government/firm value over time.

Now proceed to the Pareto frontier characterization. When $V \in FB$, $\lambda = 0$ and from (6) the investment is set at the first-best level $I = I^* = 1$. As a result, $U(V)$ is given by

$$U(V) = V^{\#} - V \text{ for } V \in [\bar{V}, V^{\#}], \tag{10}$$

where $\bar{V}$ and $V^{\#} = (E[r(I^*, p)] - I^*)/(1 - \delta) = 1/(1 - \delta)$ are the left and the right ends of the FB. There are multiple solutions[29] to the maximization prob-

[28] In comparison to Thomas and Worrall (1994), formal institutions result in a stronger incentive to increase V_1. To see why, consider an increase in V_1. By (PK), it needs to be accompanied by a reduction in T_1 such that the government still gets V. When $C = 0$, the latter does not affect the value of expropriation. However, when $C > 0$, a decease in T_1 also decreases the expected value of expropriation, as it does not happen with probability 1. As a result, it relaxes (SE). This additional incentive will not matter along SB, as (LL) will restrict V_1. However, it will imply, for instance, that a stationary equilibrium is not feasible at the left-most end of FB, see more in footnote 30.

[29] $U'(V_0) = U'(V)$ does not imply $V_0 = V$ if $V \in FB$ because then $U'(V) = -1$ everywhere.

lem (Fmax)–(PC). The set of solutions (V_0, V_1) for a given V is described by the following inequality system:

$$\begin{array}{l} \delta V_1 - (1-C)\,(4 - 2V + \delta V_0 + \delta V_1) \geq 0, \\ 2V - \delta V_0 - \delta V_1 \geq 0 \\ V, V_0, V_1 \in [\bar{V}, V^{\#}]. \end{array} \tag{11}$$

We solve for minimal $\bar{V}$ satisfying (11) to define the broadest set of V such that $I = I^*$. Notice that for such a minimal V the first inequality in (11) is more likely to hold for a small V_0 and for large V_1. So we set $V = V_0 = \bar{V}$. This, combined with (LL), implies that $V_1 \leq V/\beta$. As a result, there are two possible sub-cases.

Case 1.1. If $\bar{V} < \beta V^{\#}$ (that is, if it takes more than one $1/\beta$-step to cross FB), then $V_1 = V/\beta$; substituting it into the system (11) we get $\bar{V} = \tilde{V} = \dfrac{4(1-C)}{2-\delta}$. The condition relating $\bar{V}$ and $V^{\#}$ implies that this case takes place when $\delta \geq \dfrac{4-4C}{5-4C}$.

Case 1.2. If instead $\bar{V} \geq \beta V^{\#}$ then (PC) binds and the highest possible $V_1 = V^{\#}$; then system (11) yields $\bar{V} = \tilde{\tilde{V}} = \dfrac{4(1-C)-(4-3C)\delta}{(1-C)(1-\delta)(2-\delta)}$. This case takes place when $\dfrac{2-2C}{3-2C} \leq \delta < \dfrac{4-4C}{5-4C}$.

Let us turn to the SB. When $V \in SB$, (SE) binds (i.e. $\lambda > 0$), and the investment level is suboptimal, $I < I^*$, so from (9)

$$U'(V_0) = U'(V) > -1, \tag{12}$$

and the Pareto set is no longer linear.

Assuming the function $U(\cdot)$ is strictly concave, $U'(V)$ is decreasing in V for $V \in SB$, and it follows from (7), (8) and (12) and (LL') that

$$V_0 = V \leq V_1 \leq \frac{V}{\beta}. \tag{13}$$

Note that it is not possible to have $\mu = \nu = 0$ for $V \in SB$ as long as $C > 0$, since constraints (8) and (12) need to be satisfied. Hence, if $C > 0$ then either (LL) binds and $V_1 = V/\beta$, or (PC) does and $V_1 = V^{\#}$.

With this in mind, we proceed to recursively describe the SB. Start with the segment of the SB neighboring FB from the left.

In Case 1.1, the segments of SB, starting from the one neighboring FB from the left, and going towards smaller V, are determined as $S_1 = [\beta\tilde{V}, \tilde{V})$, $S_2 = [\beta^2\tilde{V}, \beta\tilde{V})$, ..., $S_k = [\beta^k\tilde{V}, \beta^{k-1}\tilde{V})$. For i-th segment, the Pareto frontier is determined by solving (Fmax) with (SE) equalized under $V_1 = V/\beta$, $V_0 = V$, and $U(V_1) = F_{i-1}(V_1)$, $i = 1, ...k$, where $F_i(.)$ is an auxiliary function defined by functional form of U(.) on i-th SB segment, $F_i(V) = U(V)$ on S_i, and $F_0(V) = V^{\#} - V$. We obtain

$$U(V) = a_i V^2 + b_i V + c_i \tag{14}$$

where a_i, b_i, c_i can be determined recursively from the Bellman equation (Fmax):

$$a_i = \frac{a_{i-1}}{\beta} - \frac{2-\delta}{8(1-C)^2}, \quad b_i = b_{i-1} + \frac{1}{1-C}, \quad c_i = \beta c_{i-1}, \tag{15}$$

and

$$a_1 = -\frac{2-\delta}{8(1-C)^2}, \quad b_1 = \frac{C}{1-C}, \quad c_1 = \frac{\beta}{1-\delta}. \tag{16}$$

The level of investment at each segment is

$$I(V) = \left(\frac{2-\delta}{4(1-C)}V\right)^2 = \left(\frac{V}{\tilde{V}}\right)^2. \tag{17}$$

The left bound of the Pareto frontier $V_{\min}$ is reached at the maximum of $U(V)$, when $U'(V) = 0$ i.e.

$$V_{\min} = \frac{b_k}{-2a_k} \tag{18}$$

where k is such that $V_{\min}$ is between $\beta^k \tilde{V}$ and $\beta^{k-1}\tilde{V}$. Note that $V_{\min}$ is positive since $b_k > 0$. At this point, the firm gets the largest profits.

In turn, the number of steps to reach the FB, k, is given by:

$$k = \left\lceil \frac{\ln\left(V_{\min}/\bar{V}\right)}{\ln \beta} \right\rceil \tag{19}$$

In Case 1.2 the recursive procedure is the same as in Case 1.1, but at the first step – i.e., at the segment of the SB neighboring FB from the left, – $V_1 = \min(V/\beta, V^{\#})$. As our further analysis mostly concerns Case 1.1, we do not provide the solution of case 1.2 here, but it is available on request.

Proof of Lemma 1 For expositional clarity, we limit the analysis of this section and of Proof of Proposition 2 to Case 1.1. Most of the results of this section extend to Case 1.2 and the proofs are available on request. The only result that we could not establish for case 1.2 so far is the existence of an equilibrium with more backloading of taxes under weaker institutions.

In this Lemma, we want to establish that k, the number of periods with a high price realization needed to reach the first best part of Pareto frontier, is decreasing in C. The value of k is determined by the inequalities

$$\beta^k \leq \frac{V_{\min}}{\tilde{V}} < \beta^{k-1}. \tag{20}$$

Combining the definition of $V_{\min}$ (18), with (15) and (16), we obtain

$$V_{\min} = \frac{2(k-1+C)(1-C)(1-\beta^2)}{\beta(\beta^{-k}-1)} \text{ if } C_k \leq C \leq C_{k-1} \tag{21}$$

where

$$C_k = \sum_{i=0}^{k} \beta^i - k = \frac{1-\beta^{k+1}}{1-\beta} - k. \tag{22}$$

Here $[C_k, C_{k-1}]$ is the segment of C values satisfying $\beta^k \tilde{V} \leq V_{\min} \leq \beta^{k-1}\tilde{V}$.

Using (21), we obtain

$$\frac{V_{\min}}{\tilde{V}} = \frac{\beta^{-1}-1}{\beta^{-k}-1}(C+k-1) \tag{23}$$

We need to show that k as determined by conditions (20) and (23)

$$\beta^k \leq \frac{\beta^{-1}-1}{\beta^{-k}-1}(C+k-1) < \beta^{k-1} \tag{24}$$

is decreasing in C.

Consider an auxiliary implicit equation defining a continuous variable $x \geq 0$ as a function of $C \in [0,1]$

$$\frac{\beta^{-1}-1}{\beta^{-x}-1}(C+x-1) - \beta^x = 0. \tag{25}$$

Note that this equation is a continuous version of the condition (24) which (step-wise) defines a natural number k as a function of C. Thus, if we can show that x is decreasing in C in equation (25), k is decreasing in C. Define

$$F(C,x) \equiv \frac{\beta^{-1}-1}{1-\beta^x}(C+x-1),$$

then equation (25) is equivalent to $F(C,x)-1=0$. Taking full derivative of this equation we get

$$\frac{dx}{dC} = -\frac{F_C(C,x)}{F_x(C,x)} = -\frac{1-\beta^x}{(C-1)\beta^x \ln\beta + x\beta^x \ln\beta - \beta^x + 1} \leq 0$$

as $\beta < 1$, $C \leq 1$ and $-\beta^x + x\beta^x \ln\beta + 1$ increases in $x \geq 0$ and is zero at $x=0$. As a result, x is a decreasing function of C as defined by implicit equation (25).

Proof of Proposition 2 This proposition follows from Lemmas 2 and 3.

Lemma 2. *The cumulative shares of investment $CS^I_{\bar{n}}$ and production $CS^r_{\bar{n}}$ increase in C for any fixed $\bar{n}$, N and δ.*

Proof of Lemma 2 We prove the result for investment, the proof for production is fully analogous. First, note that if both (SE) and (LL') bind then the investment is given by (17): $I = \left(V/\tilde{V}\right)^2$. This means that for all $V \in [0, V^{\#}]$

$$I = \min\left\{\left(V/\tilde{V}\right)^2, 1\right\}. \tag{26}$$

Note that on the SB part of the equilibrium path of V starting from $V = V_{\min}$, V increases at a rate of $1/\beta$. Thus, if $n \leq k$ then the value of I is given by

$$I_n = \beta^{-2(n-1)}\left(V_{\min}/\tilde{V}\right)^2. \tag{27}$$

Hence the cumulative share of investment $CS^I_{\bar{n}}$ defined by (1) is given by

$$CS^I_{\bar{n}} = \frac{e\left(V_{\min}/\tilde{V}\right)^2 + f}{\sum_{n=1}^{k}\beta^{-2(n-1)}\left(V_{\min}/\tilde{V}\right)^2 + N - k} \tag{28}$$

where

$$\begin{cases} e = \sum_{n=1}^{\bar{n}} \beta^{-2(n-1)}, \ f = 0, & \text{if } \bar{n} \leq k, \\ e = \sum_{n=1}^{k} \beta^{-2(n-1)}, \ f = \bar{n} - k, & \text{if } \bar{n} > k. \end{cases}$$

In both ranges of $\bar{n}$,

$$e(N-k) > f \sum_{n=1}^{k} \beta^{-2(n-1)}$$

for all $\bar{n} = 1, \ldots, N-1$, so $CS^I_{\bar{n}}$ is increasing in $V_{\min}/\tilde{V}$.

To prove that $CS^I_{\bar{n}}$ increases in C it suffices to establish two things: 1) that $V_{\min}/\tilde{V}$ increases in C on each segment $[C_k, C_{k-1}]$ where k is constant, and 2) that $CS^I_{\bar{n}}$ is continuous in C at each threshold C_k where k changes.

The first part is trivial - from (23) it follows that $V_{\min}/\tilde{V}$ is continuous and increasing in C on each segment $[C_k, C_{k-1}]$.

Now show that both the numerator and denominator of $CS^I_{\bar{n}}$ are continuous at the thresholds. Start with the denominator and show that the difference between the values of it to the left and to the right of C_k is zero. Using the expression (23) for $V_{\min}/\tilde{V}$ to the left and to the right of of C_k and the expression (22) for C_k, we get

$$\left(\sum_{n=1}^{k+1} \beta^{-2(n-1)} \left(\frac{\beta^{-1}-1}{\beta^{-k-1}-1}(C_k + k) \right)^2 + N - k - 1 \right)$$
$$- \left(\sum_{n=1}^{k} \beta^{-2(n-1)} \left(\frac{\beta^{-1}-1}{\beta^{-k}-1}(C_k + k - 1) \right)^2 + N - k \right)$$
$$= \left(\sum_{n=1}^{k+1} \beta^{-2(n-1)} - \sum_{n=1}^{k} \beta^{-2(n-1)} \right) \left(\beta^k\right)^2 - 1 = 0.$$

Regarding the numerator, if $\bar{n} < k$, the difference between its values to the left and to the right of C_k is trivially zero. If $\bar{n} \geq k$, the proof proceeds similarly to the one for the denominator.

Lemma 3. *(a) Taxes are zero until the path reaches FB, and the number of such periods decreases in C. (b) There exist equilibria in which the cumulative share of taxes $CS^T_{\bar{n}}$ increases in C for any fixed $\bar{n}$, N and δ.*

Proof of Lemma 3 Result (a) follows from the proof of Lemma 1. Let us establish result (b). As discussed earlier, unlike investment or production, the tax schedule may depend on the choice among multiple solutions in the first-best segment. Consider the equilibrium that originates at $V_{\min}$, reaches efficient frontier at $V_{\min}/\beta^k$, then proceeds to $V_1 = \tilde{V}/\beta$ and stays there stationary.[30]

Then T_n is zero in periods $n \leq k$. At period $k+1$ the tax is

$$T_{k+1} = 2V - \delta V_0 - \delta V_1 = (2-\delta)V_{\min}/\beta^k - \tilde{V}/\beta,$$

[30]Notice that a stationary equilibrium satisfying (SE) constraint implies $\delta V - (1 - C)(4 - 2V + 2\delta V) \geq 0$ or equivalently $V \geq \frac{4(1-C)}{2-\delta-2C(1-\delta)}$. This implies that when $C > 0$, a stationary equilibrium is impossible at $\tilde{V} = \frac{4(1-C)}{2-\delta}$, but can take place at $\tilde{V}/\beta$.

and for $n > k+1$ it is given by

$$T_n = 2(1-\delta)\tilde{V}/\beta.$$

As a result, $CS_{\bar{n}}^T = 0$ if $\bar{n} < k+1$, while for $\bar{n} \geq k+1$ it is given by

$$\begin{aligned} CS_{\bar{n}}^T &= \frac{((2-\delta)V_{\min}/\beta^k - \tilde{V}/\beta) + (\bar{n}-k-1)2(1-\delta)\tilde{V}/\beta}{((2-\delta)V_{\min}/\beta^k - \tilde{V}/\beta) + (N-k-1)2(1-\delta)\tilde{V}/\beta} \\ &= 1 - \frac{(N-\bar{n})}{(2-\delta)\beta^{-k+1}\left(V_{\min}/\tilde{V}\right) - 1 + (N-k-1)2(1-\delta)} \end{aligned}$$

Since $V_{\min}/\tilde{V}$ increases in C, $CS_{\bar{n}}^T$ increases in C for each k (that is, on each segment $[C_k, C_{k-1}]$). The proof that $CS_{\bar{n}}^T$ is continuous in C at each threshold C_k follows the above approach using (22) and (23) and the definition of β. As a result, $CS_{\bar{n}}^I$ is increasing in C.[31]

Proof of Proposition 3 To prove this result, it is sufficient to note that after the period that the efficient frontier is reached the cumulative share of investment and production increase by the same amount each period, and this incremental change decreases in the institutional quality. For example, for investment

$$\Delta CS_{\bar{n}}^I = CS_{\bar{n}+1}^I - CS_{\bar{n}}^I = \frac{1}{\sum_{n=1}^{k} \beta^{-2(n-1)}\left(V_{\min}/\tilde{V}\right)^2 + N - k}$$

for any $\bar{n}$ such that $k \leq \bar{n} < N$. The proof of Lemma 2 shows that the denominator of this expression increases in C, so the expression decreases in C. Now, consider two levels of institutions, $C_{weak} < C_{strong}$. By Lemma 1 from period $\kappa = k_{weak}$ investment is efficient for either institutional level. Then for any $\bar{n} \geq \kappa$, the incremental change in the cumulative share of investment for C_{weak} will be higher than for C_{strong}. This means, that the cumulative share of investment under weak institutions is catching up with the one under strong institutions, or equivalently, that investment backloading decreases over time. The proof for production is fully analogous.

[31]Note that this result may depend on equilibrium selection. For example, it can be shown that the reverse is true in an equilibrium that originates at $V_{\min}$, reaches efficient frontier at $V_{\min}/\beta^k$, then proceeds to, and stabilizes at, $V^{\#}$.