Are Credit Rating Agencies Punishing Petrostates for Energy Transition Risks?

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ABSTRACT

The energy transition is expected to leave fossil fuel producers with weakened economies and stranded assets, but the time horizon of these effects is uncertain. This article offers a window into these effects by studying the sovereign credit ratings of petrostates. Credit ratings are both forward-looking indicators of their economic outlook and determinants of petrostates' ability to raise capital, and may thus already reflect concerns about the energy transition's anticipated effects. Using data on sovereign credit rating decisions, this article studies changes in petrostate ratings over time. We find some signs that they are declining, but also that this is not primarily the result of systematic downgrades. For the time being, credit rating agencies are instead rewarding petrostates less for high oil prices and punishing them more for low levels of economic diversification. The short-to-medium term risk horizon of rating agencies means that future downgrades could come suddenly and steeply.

Keywords: energy policy, energy transition, oil, petrostates, renewable energy, credit ratings

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1. INTRODUCTION

The next three decades will see a steep rise in the adoption of renewable energy and electric vehicles. This will pose challenges for countries that rely on fossil fuel exports, including major oil producers (petrostates). Between 2000 and 2018, nearly 25 countries relied on oil rents for upwards of 10% of GDP, and for 11 of them oil rents accounted for more than 25% of GDP. Declining oil demand will over time reduce both the amount of oil petrostates can sell and the price they are paid for this oil. The United Nations' Inevitable Policy Response Forecast Policy Scenario (2019) estimates that oil demand could halve by 2050, while the International Energy Agency's Sustainable Development Scenario forecasts that the price of oil could decline by nearly 20% by 2040 (Fitch, 2021a).

Declining oil revenue will weaken the ability of petrostates to repay their debts, raising the risk of default (Mathiesen, 2018). This prospect logically should cause the "Big Three" leading credit ratings agencies—Standard & Poor's (S&P), Moody's, and Fitch—to downgrade the sovereign credit ratings of petrostates. Credit ratings are a key determinant of access to global

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capital markets, and specifically of their ability to borrow at favorable interest rates (Cantor and Packer, 1996). In the past, major oil producers have borrowed heavily on the expectation of future oil revenues (Nooruddin, 2008).

Credit rating agencies rely on a variety of political, social, and economic indicators that capture current conditions and trends to make their assessments, as shown in Table 1. Unsurprisingly, there is a strong correlation between sovereign credit ratings and a variety of economic and political variables, including GDP per capita, GDP growth, inflation, external debt, default history, and quality of political and economic institutions (Afonso, 2003; Afonso et al., 2011; Butler and Fauver, 2006; Cantor and Packer, 1996; Chee et al., 2015; Reinhart, 2002). However, while the major ratings agencies state that they consider environment, social, and governance (ESG) concerns, the agencies handle them on an ad hoc basis. S&P and Moody's, for example, recognize that governments dependent on hydrocarbons may face "transition risks" from long-term declining oil demand, but do not lay out clear criteria by which these risks should lead to downgrades (Moody's, 2019a; S&P Global, 2017a, 2017b, 2018, 2019).

TABLE 1
Summary of the main criteria used in the methodologies of the Big Three credit rating agencies (Fitch, 2021c; Moody's, 2019a; S&P Global, 2017a).

S&P	Moody's	Fitch
Institutional: Stability and effectiveness of government policy-making processes.	*Institutions and governance strength*: Institutional quality and policy effectiveness.	*Structural features*: Governance quality, wealth and flexibility of economy, political stability and capacity, and financial sector risks.
Economic: Wealth, growth prospects, and economic diversification.	*Economic strength*: Wealth, growth prospects, and economic diversification.	*Macroeconomic performance, policies, and prospects*: Policy framework, growth, inflation, and exchange rate.
External: Ability to raise funds from abroad.	*Fiscal strength*: Debt and interest payments.	*Public finances*: Debt, fiscal balance, and fiscal policy.
Fiscal: Debt and ability to raise revenue domestically.	*Susceptibility to event risk*: Political and geopolitical risk, government liquidity, and banking sector risk.	*External finances*: Balance of payments, external balance sheet, and external liquidity.
Monetary: Currency exchange regime and monetary policy.		

Some observers argue that credit rating agencies and financial markets are underestimating the risk of default for governments and firms that depend on fossil fuel extraction (Battiston et al., 2017; Carbon Tracker, 2021, 2011; Colgan, 2018; Lou and Dallos, 2016; Mathiesen, 2018). But this research is largely abstract and speculative; there is a lack of empirical research on the magnitude of changes in petrostate credit ratings and whether some petrostates are being affected more than others.

Thus, neither the rubrics used by ratings agencies nor the existing research on sovereign credit ratings provide substantial insight into the impact of energy transition and stranded fossil fuel asset risk on credit ratings and the time horizon of this impact. In this article, we attempt to bring empirical evidence to bear by directly measuring the degree to which petrostate credit ratings have been lowered due to concerns about energy transition risk. We assess whether petrostate credit ratings have declined over time due to energy transition risks; whether transition risk concerns are offset during periods of higher oil prices; and whether the credit ratings of petrostates with more diversified economies are penalized less than those with less diversified economies.

Our analysis makes contributions to two fields of research. First is the scholarly literature on the energy transition. We contribute to this literature by empirically assessing a specific channel through which the transition might influence fossil fuel producers: sovereign credit ratings. They are especially useful indicators of the pace and scope of the energy transition's effects on petrostates because they are leading indicators, and thus may register an impact before it is felt by petrostate economies. In other words, the anticipated effects of the energy transition are likely to impact petrostate credit ratings before changes in the oil market affect present-day economic conditions in petrostates.

Our second contribution is to the literature on sovereign credit ratings. Our analysis not only identifies correlates of credit ratings using current or recent indicators, as some of the existing literature does (Afonso, 2003; Afonso et al., 2011; Butler and Fauver, 2006; Cantor and Packer, 1996; Chee et al., 2015; Reinhart, 2002), but also studies how credit rating agencies respond to long-term risks over time. Moreover, we home in on the relationship between energy transition risk and credit ratings by connecting quantitative trends in credit ratings with qualitative evidence drawn from the reasoning of credit rating agencies.

In the next section, we discuss why energy transition risks might be expected to shape petrostate credit ratings. We then proceed to describe our research design, discuss the quantitative results, and present qualitative evidence on the mechanisms by which transition risks might be shaping petrostate credit ratings. We conclude with a discussion of implications.

2. PETROSTATE CREDIT RATINGS AND ENERGY TRANSITION RISKS

Petrostates—which, as we describe in more detail below, we define as countries with oil incomes of at least 10% of GDP or USD 300 per capita—depend heavily on oil rents as a source of government revenue. Among petrostates, oil and gas typically makes up a share of government revenue that is at least double the share of the overall economy, with thirteen of them depending on oil and gas revenue for more than half of their government revenue (Ross, 2012; Coffin and Grant, 2021). This revenue has allowed many of them to create extensive welfare states for their citizens, distribute patronage, and invest in a variety of projects both at home and abroad (Ross, 2012; Ashford, 2022). An energy transition that exerts downward pressure on global demand for oil thus imperils petrostates governments' ability to raise revenue—and, hence, to pay their debts. Under low-carbon scenarios, petrostate government revenues could decline by up to nearly USD 10 trillion by the early 2040s—a nearly 50% revenue shortfall, on average, compared to the present day (Coffin and Grant, 2021).

Thus, the central hypothesis we test in this paper is that energy transition risks have increasingly constrained petrostate sovereign credit ratings over time:

Hypothesis 1: Petrostate credit ratings have declined over time due to increasing concerns about energy transition risks.

Additionally, if energy transition risks are affecting petrostate sovereign credit ratings, we might expect to see other pieces of evidence. The first is that petrostate credit ratings are no longer buoyed by high oil prices. Because oil rents comprise such a large share of their government revenue, petrostates' ability to raise revenue is quite sensitive to changes in the price of oil. When oil prices are high, petrostates can pay their debts with comparative ease. When prices are low, by contrast, paying off their debts becomes more difficult for petrostates, which often resort to cutting government spending (Meierding, 2022).

The energy transition, however, may attenuate the link between oil prices and petrostate credit ratings. Because petrostates face the prospect of stranded assets due to unburnable oil reserves, credit rating agencies may not reward them for high oil prices as that prospect becomes nearer, based on the logic that oil's long-term decline represents a threat to petrostates' creditworthiness that outweighs temporary upward fluctuations in the price of oil, and that these upticks are likely to be fleeting as global demand slows, peaks, and ultimately declines (Van de Graaf, 2018; Van de Graaf and Bradshaw, 2018).

Thus, while we might expect higher oil prices to have buoyed petrostate credit ratings in earlier years, when energy transition risks were less salient, this link should be weaker as time goes on:

Hypothesis 2a: Petrostate credit ratings are higher when oil prices are higher.
Hypothesis 2b: The link between petrostate credit ratings and oil prices has declined over time due to increasing concerns about energy transition risks.

Conversely, energy transition risks may lead credit rating agencies to punish petrostates more for having undiversified economies. In the past, petrostates' ability to pay their debts depended largely on the value of their oil. Indeed, existing research suggests that petrostates have on the whole largely failed to diversify their economies (Hendrix, 2019; Ross, 2019; Lashitew et al., 2021). The reasons for this are numerous, and includes not only the influence of vested interests in fossil fuels and the "Dutch Disease," but also a comparative lack of urgency, as petrostates could for much of the last fifty years expect oil prices to eventually rebound (Bahar and Santos, 2018; Corden and Neary, 1982; Ross, 2012; Venables, 2016).

Expectations of impending declines in oil demand and the possibility of large amounts of stranded assets, however, mean that oil revenue will not represent the same lifeline that allows governments to honor their debts. As a result, as time goes on, it should matter more whether petrostates have diversified economies that can allow their governments to continue collecting revenue even as oil rents decline.

Hypothesis 3a: Petrostate credit ratings are higher when their economies are more diversified.
Hypothesis 3b: The link between petrostate credit ratings and economic diversification has increased over time due to increasing concerns about energy transition risks.

It is important to note that it is not our intention to treat credit ratings as an objective measure of a country's creditworthiness and long-term outlook. Rating agencies can make incorrect assessments, and indeed as noted above there has been some speculation that they are systematically underestimating petrostates' credit risks (Colgan, 2018). We choose to focus on credit ratings both because they are one of the few leading indicators of economic performance and creditworthiness that can be compared across countries, and because credit ratings themselves have an impact on the ability of a state to borrow. We thus use this paper both as an opportunity to investigate how energy transition risks are shaping petrostate sovereign credit ratings, and as an opportunity to reflect on the degree to which the methodologies of rating agencies are accurately capturing the challenges facing petrostates in the coming decades.

3. METHODS

To assess changes in petrostate credit ratings over time, we use monthly time-series cross-sectional data covering 153 countries between 1992 and 2019, drawing data on sovereign credit ratings from the three major agencies: Moody's, S&P, and Fitch.[1] Following the established practice in studies on sovereign credit ratings (Chee et al., 2015; Teixeira et al., 2018), our dependent variable is the arithmetic average of the credit ratings assigned by the Big Three, which were converted to a 21-point scale with higher values indicating better ratings. In Table 2, we present the numerical conversion of the credit ratings assigned by each credit rating agency.

TABLE 2
Numerical conversion of the credit ratings assigned by Moody's, Fitch, and S&P, respectively.

	Moody's	Fitch	S&P
21	Aaa	AAA	AAA
20	Aa1	AA+	AA+
19	Aa2	AA	AA
18	Aa3	AA-	AA-
17	A1	A+	A+
16	A2	A	A
15	A3	A-	A-
14	Baa1	BBB+	BBB+
13	Baa2	BBB	BBB
12	Baa3	BBB-	BBB-
11	Ba1	BB+	BB+
10	Ba2	BB	BB
9	Ba3	BB-	BB-
8	B1	B+	B+
7	B2	B	B
6	B3	B-	B-
5	Caa1	CCC	CCC+
4	Caa2	CC	CCC
3	Caa3	C	CCC-
2	Ca	RD	CC
1	C or below	D or below	C/D or below

Our main independent variable is countries' level of *oil income,* which we interact with the passage of time since we would expect to see evidence that petrostates' credit ratings have declined over time as concerns about climate change and expectations of a rising uptake of renewable energy and electric vehicles have grown. To measure oil income, we use data on annual oil production and oil prices from 1992. We then create measures of oil income as a percentage of gross domestic product and per capita, using GDP and population data from the World Development Indicators (WDI) (World Bank, 2021). Oil income is heavily skewed, with a small number of countries producing a large portion of the world's oil and most countries producing little to none. Thus, in accordance with the practice in the existing literature, we create binary measures of petrostate status (Colgan, 2013; Ross, 2019, 2012). The first of these

1. Our ratings are the long-term ratings (i.e., for obligations with a maturity of more than a year) on foreign currency debt. This is because we are interested in the perceived long-term creditworthiness of petrostates, and because while local and foreign currency credit ratings are often identical, the foreign currency rating is typically the lower of the two when the two diverge. Thus, we might expect to see evidence that transition risks are shaping foreign currency ratings first. Not all countries have data available for every time period; data are included from as many countries as possible in each time period.

captures whether oil income accounted for at least 10% of a country's GDP between 1992 and 2019 and proxies for oil *dependence*, while the second captures whether the country produced at least USD 300 in oil income per capita over the same period and proxies for oil *abundance* (Colgan, 2013; Ross, 2019). Figures A4 and A6-A7 in the supplementary materials show that the results are robust to measuring petrostate status using >20% of GDP and >USD 500 per capita thresholds. The oil production and oil price data are from the U.S. Energy Information Administration and Our World in Data, which are primarily based on the BP Statistical Review of World Energy (Our World in Data, 2021; U.S. Energy Information Administration, 2021). Data are all in constant 2010 U.S. dollars, adjusted using the U.S. Office of Management and Budget's deflator estimates. The lists of countries included under both thresholds are included in Tables A1 and A2 in the supplementary material. Some scholars use net oil export revenue rather than the value of oil production to capture oil income (Colgan, 2013). However, as Ross notes, doing so biases oil income upwards for producers that are currently poorer, as they are likely to consume less of the oil they produce (Ross, 2019, 2012).

To capture changing dynamics over time, we use a linear time trend. Additionally, because expectations about the energy transition have grown in recent years, one might expect a non-linear impact as well, with petrostate credit ratings declining more sharply in recent years. Thus, we also use a dummy variable for the post-2010 period as a robustness check.

Our study employs ordinary least squares regression to estimate our models, a method commonly utilized in existing research exploring the determinants of sovereign credit ratings (e.g., Cantor and Packer, 1996; Afonso et al., 2011; Afonso, 2003; Chee et al., 2015). Notably, some studies have employed discrete choice models due to the discrete nature of credit ratings (e.g., Teixeira et al., 2018). However, in our analysis, the dependent variable is an arithmetic average of credit ratings from the Big Three agencies, rendering it continuous rather than discrete. Still, we conducted supplementary analysis using discrete choice models, specifically ordinal probit models, by rounding down our dependent variable to be discrete. The findings, presented in Table A9 in the supplementary materials, indicate that the results remain substantively consistent. Moreover, to address country-level and temporal variations, we included a lagged dependent variable. Credit rating agencies often exhibit cautiousness in altering ratings, with downgrades typically following periods of economic decline and upgrades ensuing after sustained improvement. The inclusion of the lagged variable accommodates this "stickiness" by acknowledging that a country's present rating is influenced by its trajectory. In other words, the lagged rating captures this persistence and enables the model to distinguish between countries with divergent creditworthiness histories. Additionally, the lagged dependent variable aids in accounting for unobserved factors that are likely to be correlated with both past and present creditworthiness. Furthermore, we examined the robustness of our results by incorporating country fixed effects into the models to address potential country-level heterogeneity. The findings, illustrated in Appendix Figures A6 and A7, demonstrate that our main findings remain consistent even after accounting for time-invariant country-specific factors.

Also, we include a variety of control variables to mitigate concerns about omitted variable bias. Existing studies have shown that both macroeconomic variables (e.g., GDP per capita, debt, and inflation) and political variables (e.g., political stability) affect the country-level credit ratings (Afonso et al., 2011; Bissoondoyal-Bheenick, 2005; Erdem and Varli, 2014; Hilscher and Nosbush 2010; Maltritz and Molchanov, 2014; Mellios and Paget-Blanc, 2006; Teixeira et. al. 2018). We control for the natural logarithm of each country's GDP per capita, current account balance (% of GDP), and inflation (annual %), political stability, and economic growth (i.e., GDP growth rate), which can be associated with both the credit ratings and oil prices as well as oil production.[2] As a robustness check, we run our models by including more controls and found that the inclusion of more controls do not alter our main findings (Table A8 in the supplementary materials).

The data for economic indicators are from the WDI and political stability data are from the World Bank Governance Indicators (WGI) (World Bank, 2021). Additionally, we include month fixed effects to account for variation within years (e.g., due to differences in oil demand throughout the year).

The model specification we use is as follows:

$$\begin{aligned}\text{CreditRating}_{i,t,m} &= \beta_1 \text{Petrostate}_i + \beta_2 \text{Time}_{t,m} + \beta_3 \text{Petrostate}_i * \text{Time}_{t,m} \\ &\quad + \beta_4 \text{CreditRating}_{i,t,m-1} + \delta_m + \gamma \text{X}_{i,t} + \epsilon_{i,t,m}\end{aligned}$$

where i represents countries, t represents years, and m represents months. *CreditRating* is a country's average credit rating across the Big Three rating agencies, *Petrostate* is a binary indicator of petrostate status, *Time* is an indicator of time (whether a linear time trend or a time period dummy variable), $\text{X}_{i,t}$ is a vector of country-year control variables, δ is a vector of month fixed effects, and $\epsilon_{i,t,m}$ is a stochastic error term. As a robustness check, we employ cubic time trends (t, t^2, and t^3) in lieu of a linear time trend and ascertain that the principal findings remain largely unaffected. Also, to account for potential non-linear effects, we further examine semi-parametric kernel smoothing estimation results for the marginal effects.

4. RESULTS

In this section we begin by presenting raw credit rating data over time, followed by multivariate regression results estimating (1) change in credit ratings over time, controlling for confounders; (2) the effect of oil prices on petrostate credit ratings over time; and (3) the effect

TABLE 3
Summary statistics of key variables.

	Mean	Median	SD	Min	Max	Observations
Average credit ratings	12.69	12.00	5.18	1	21.00	38239
Benchmark oil price (constant 2010 USD/barrel)	48.30	38.65	26.22	12	126.88	52814
Petrostate (binary, oil income > 10% of GDP)	0.12	0.00	0.32	0	1.00	52814
Petrostate (binary, oil income > 300 USD per capita)	0.18	0.00	0.39	0	1.00	52814
GDP.P.C. (logged, country-year level)	8.71	8.68	1.47	5	11.86	4164
Current account (country-year level)	-2.15	-2.49	9.16	-50	45.45	3702
Inflation, consumer prices (annual %, country-year level)	27.86	3.71	424.46	-30	23773.13	3770
Theil index (country-year level)	3.11	2.84	0.99	2	6.30	3656

2. We do not add other variables suggested by previous studies as potential determinants of country-level credit ratings, such as default, liquidity risk, debt, and corruption. This is due to their unavailability for many developing countries and petrostates. For instance, liquidity risk, defined as the ratio of short-term debt to reserves and sourced from the IMF, is accessible for only 63 countries.

of export diversification on petrostate credit ratings over time. We conclude by discussing the robustness of the findings to alternative model specifications. Summary statistics can be found in Table 3. In the following section, we supplement our quantitative findings using qualitative evidence from Big Three sovereign credit reports.

Figures 1 and 2 graphically present the main findings from the estimations when petrostates are defined as those producing oil with a value at or above 10% of GDP and \$300 per capita, respectively. The estimations for each figure (except Figures 1a and 2a) can be found in Tables 4 and 5. First, Figures 1a and 2a show the raw credit rating data for both petrostates and non-petrostates, plotted against the average monthly international benchmark oil price. (We also present a separate graph for each petrostate in Figures A1 and A2 in the supplementary material.) The data show that petrostate credit ratings tracked the price of oil through the late 2000s. Since then, however, the relationship is unclear. On the one hand, oil prices rebounded from 2016 onwards while the credit ratings of petrostates continued to decline and did so at a steeper rate than non-petrostate ratings. On the other hand, this is a short time-span and past events such as the deep but short-lived oil price dip around 2009 did not have much impact on petrostate credit ratings either.

Figures 1a and 2a, however, are purely descriptive and do not control for a variety of potential confounders like GDP per capita, political stability, and GDP growth, and the trends in the raw data may reflect factors other than assessment of transition risk. Thus, Figures 1b and 2b show estimated credit ratings over time after including relevant control variables. Consistent with the raw data, petrostate credit ratings have slightly declined over time, and especially since 2010, though this effect is small. In January 1992, oil-dependent petrostates had an average credit rating of 12.787 [95% CI: 12.754-12.820], declining to 12.723 [12.706-12.739] by January 2020, where a credit rating of 12 (equivalent to Moody's Baa3 and Fitch and S&P's BBB-) refers to an average rating or the threshold for "investment-grade." In oil-abundant states, by contrast, credit ratings were effectively flat over time. This is unsurprising, however, given that oil-abundant states are by definition wealthier on a per capita basis and can thus more easily use their oil rents to pay their debts, and are also less exposed to energy transition risks than oil-dependent petrostates. As Tables A3-A4 in the supplementary materials show, most of the decline in petrostate credit ratings has occurred since 2010 – with declines of -.026 ($p < 0.05$) for oil-dependent petrostates and -0.009 ($p < 0.05$) for oil-abundant petrostates, respectively.

Figures 1c and 2c show that while petrostates benefit from periods of higher oil prices, this positive boost has declined over time as well, though the results are weaker than the main results in Figures 1b and 2b. Whereas for most years prior to the late 2000s, the price of oil had a positive effect on petrostate credit ratings, by the late 2000s that effect disappears. The results from semi-parametric kernel smoothing estimations of the marginal effects for the petrostates, presented in Figure A4 in the supplementary materials, show substantively similar findings.

Finally, we also explore whether there is heterogeneity in how petrostate credit ratings have changed over time based on their level of export diversification. As a measure of diversification, we rely on a Theil index of export concentration, which is calculated based on country-level bilateral trade flows (Cadot et al., 2011; Giri et al., 2019). Following Cadot et al. (2011) and Giri et al. (2019), we estimate the Theil index by calculating the following formula:

$$T_i = \frac{1}{n} \sum_{k=1}^{n} \frac{x_{ik}}{\mu} \cdot \ln\left(\frac{x_{ik}}{\mu}\right),$$

where x_{ik} refers to the value of export product k in country i, and n indicates the total number of export products. μ represents the average value of export products. For the data for

FIGURE 1

Relationships between oil prices, export diversification, and credit ratings of petrostates and non-petrostates, determined based on oil dependence (oil income > 10% of GDP). a, Time trend graph for average monthly international benchmark oil price (black line) and credit ratings for petrostates (blue dotted line) and non-petrostates (red line) from January 1992 to January 2020. The left Y axis denotes oil price (USD/barrel in constant 2010 U.S. dollars), and the right Y axis denotes the average credit ratings converted to a 21-point scale with higher values indicating better ratings. **b**, Estimated credit ratings of petrostates and non-petrostates. **c**, Marginal effect of oil prices on credit ratings of petrostates and non-petrostates. **d**, Marginal effect of export diversification (measured by Theil index) on credit ratings of petrostates and non-petrostates. We coded a country as a petrostate if its oil income accounted for at least 10% of a country's GDP between 1992 and 2019 and 0 otherwise. For panels **b, c, and d**, we estimate ordinary least squares regression models including a lagged dependent variable, as well as month fixed effects, and a set of control variables such as natural logarithm of each country's GDP per capita, current account balance (% of GDP), and inflation (annual %). Panels **b, c, and d** are based on Models 4, 6, and 8 in Table A3, respectively. The shaded area refers to the 95% confidence intervals.

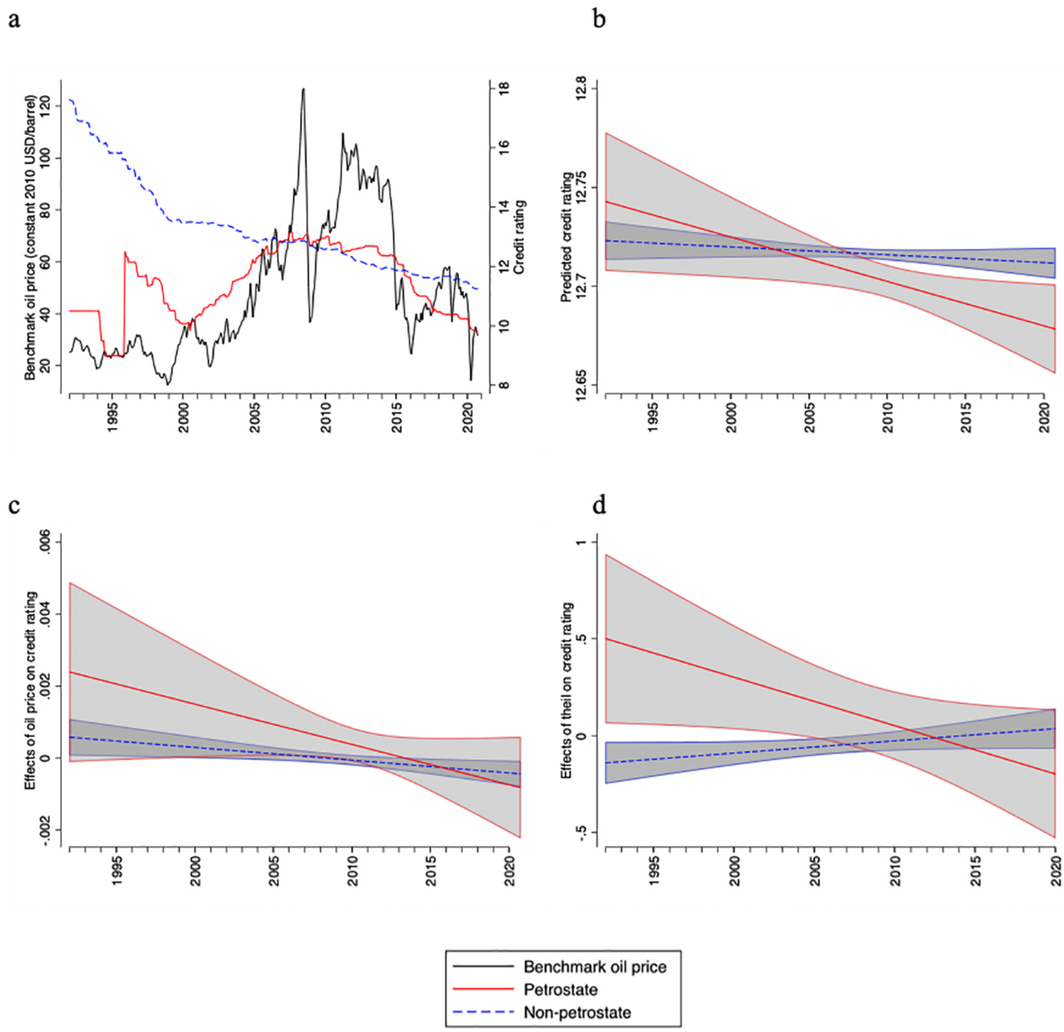

FIGURE 2

Relationships between oil prices, export diversification, and credit ratings of petrostates and non-petrostates, determined based on oil abundance (oil income > 300 USD per capita). a,Time trend graph for average monthly international benchmark oil price (black line) and credit ratings for petrostates (blue dotted line) and non-petrostates (red line) from January 1992 to January 2020. The left Y axis denotes oil price (USD/barrel in constant 2010 U.S. dollars), and the right Y axis denotes the average credit ratings converted to a 21-point scale with higher values indicating better ratings. **b**, Estimated credit ratings of petrostates and non-petrostates. **c**, Marginal effect of oil prices on credit ratings of petrostates and non-petrostates. **d**, Marginal effect of export diversification (measured by Theil index) on credit ratings of petrostates and non-petrostates. We coded a country as a petrostate if its oil income accounted for at least 300 USD per capita between 1992 and 2019 and 0 otherwise. For panels **b, c, and d**, we estimate ordinary least squares regression models including a lagged dependent variable, as well as month fixed effects, and a set of control variables such as natural logarithm of each country's GDP per capita, current account balance (% of GDP), and inflation (annual %). Panels **b, c, and d** are based on Models 4, 6, and 8 in Table A4, respectively. The shaded area refers to the 95% confidence intervals.

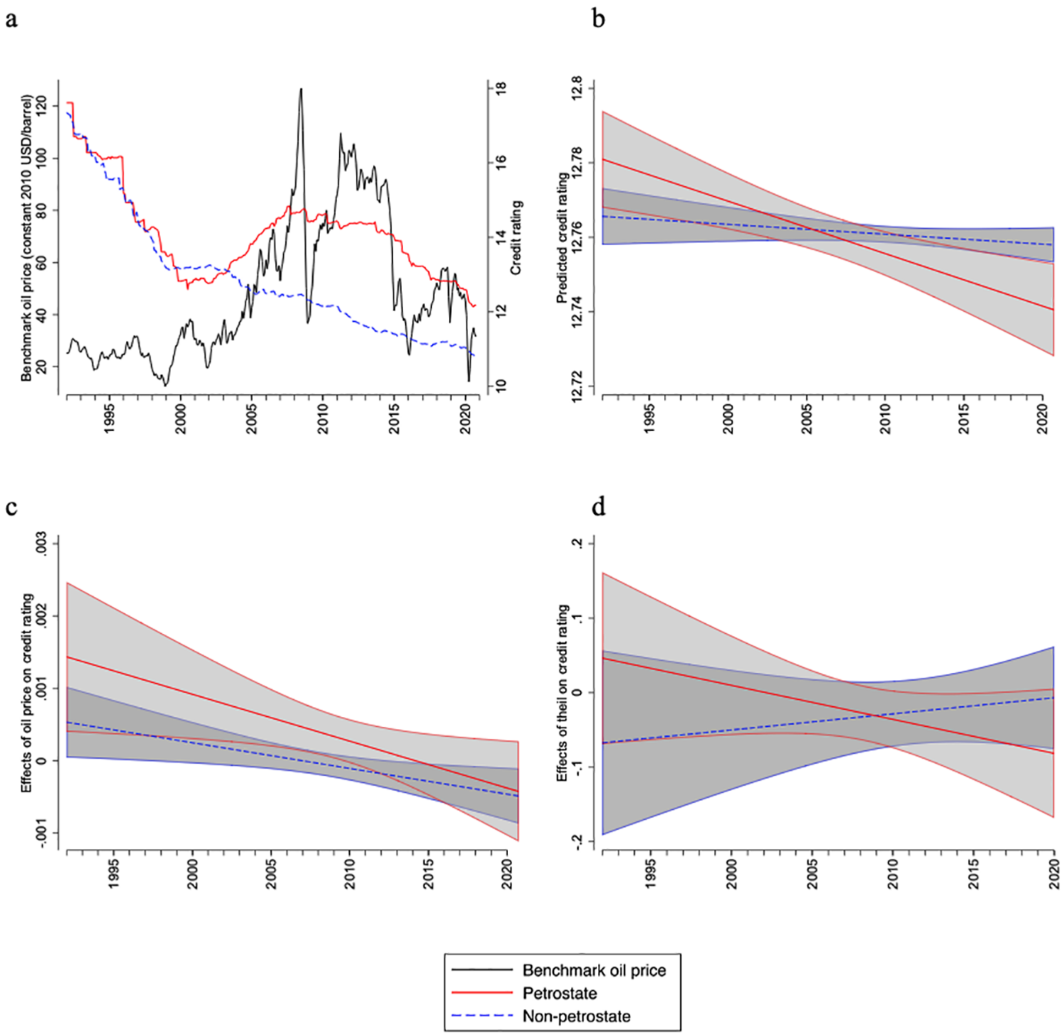

TABLE 4
Main estimation results, using a definition of petrostates that includes those producing oil with a value at or above 10% of GDP.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Credit ratings (t-1)	1.000***	0.998***	1.000***	0.998***	1.000***	0.998***	0.994***	0.968***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.002)	(0.005)
Benchmark oil price	-0.000	-0.000	-0.000	-0.000	0.000	0.001**		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
Petrostate	-0.022*	-0.021	0.009	-0.002	-0.029	-0.052	-1.285	-3.118***
	(0.013)	(0.014)	(0.014)	(0.019)	(0.033)	(0.047)	(1.391)	(1.116)
Linear trend			-0.000**	-0.000	0.000	0.000		
			(0.000)	(0.000)	(0.000)	(0.000)		
Petrostate*Oil price	0.000*	0.000	0.001**	0.000	0.002**	0.002		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)		
Petrostate*Linear trend			-0.000***	-0.000*	-0.000	0.000		
			(0.000)	(0.000)	(0.000)	(0.000)		
Oil price*Linear trend(t)					-0.000	-0.000**		
					(0.000)	(0.000)		
Petrostate*Oil price*Linear trend					-0.000	-0.000		
					(0.000)	(0.000)		
Linear trend (year)							-0.006	-0.024**
							(0.006)	(0.011)
Theil index							-0.033	-0.147**
							(0.047)	(0.058)
Petrostate*Theil							0.323	0.673***
							(0.289)	(0.243)
Petrostate*Linear trend							0.045	0.145**
							(0.063)	(0.060)
Theil*Linear trend (year)							0.000	0.006*
							(0.002)	(0.003)
Petrostate*Theil*Linear trend							-0.012	-0.031**
							(0.013)	(0.013)
GDP.P.C. (Logged)		0.005**		0.005**		0.005**		0.104***
		(0.002)		(0.002)		(0.002)		(0.023)

TABLE 4

Main estimation results, using a definition of petrostates that includes those producing oil with a value at or above 10% of GDP. (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Current account		0.001***		0.001***		0.001***		0.005**
		(0.000)		(0.000)		(0.000)		(0.002)
Inflation, consumer prices (annual %)		0.000		0.000		0.000		-0.001
		(0.000)		(0.000)		(0.000)		(0.001)
GDP growth (annual %)		0.004***		0.004***		0.004***		0.061***
		(0.001)		(0.001)		(0.001)		(0.012)
Political stability		0.006**		0.005**		0.006**		0.041
		(0.003)		(0.003)		(0.002)		(0.025)
Adjusted R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.984	0.984

Robust standard errors clustered at the country-level in parentheses.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

TABLE 5
Main estimation results, using a definition of petrostates that includes those producing oil with a value at or above $300 per capita.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Credit ratings (t-1)	1.000***	0.998***	1.000***	0.998***	1.000***	0.998***	0.993***	0.967***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.002)	(0.005)
Benchmark oil price	-0.000	-0.000*	-0.000	-0.000	0.000	0.001*		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
Petrostate	-0.018**	-0.010	-0.004	-0.004	-0.037*	-0.029	-0.336	-0.609*
	(0.008)	(0.009)	(0.007)	(0.011)	(0.021)	(0.028)	(0.239)	(0.332)
Linear trend			-0.000**	-0.000	0.000	0.000		
			(0.000)	(0.000)	(0.000)	(0.000)		
Petrostate*Oil price	0.000***	0.000	0.001***	0.000*	0.002***	0.001		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)		
Petrostate*Linear trend			-0.000***	-0.000	0.000	0.000		
			(0.000)	(0.000)	(0.000)	(0.000)		
Oil price*Linear trend(t)					-0.000	-0.000**		
					(0.000)	(0.000)		
Petrostate*Oil price*Linear trend					-0.000*	-0.000		
					(0.000)	(0.000)		
Linear trend (year)							-0.004	-0.025**
							(0.007)	(0.012)
Theil index							-0.027	-0.160**
							(0.059)	(0.072)
Petrostate*Theil							0.118	0.174
							(0.086)	(0.110)
Petrostate*Linear trend							0.013	0.038**
							(0.012)	(0.017)
Theil*Linear trend (year)							-0.000	0.006
							(0.003)	(0.004)
Petrostate*Theil*Linear trend							-0.004	-0.009
							(0.004)	(0.006)
GDP.P.C. (Logged)		0.004		0.004*		0.004*		0.094***
		(0.002)		(0.002)		(0.002) 0		(0.023)

TABLE 5

Main estimation results, using a definition of petrostates that includes those producing oil with a value at or above \$300 per capita. (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Current account		0.001***		0.001***		.001***		0.004**
		(0.000)		(0.000)		(0.000)		(0.002)
Inflation, consumer prices (annual %)		0.000		0.000		0.000		-0.001
		(0.000)		(0.000)		(0.000)		(0.001)
GDP growth (annual %)		0.004***		0.004***		0.004***		0.061***
		(0.001)		(0.001)		(0.001)		(0.012)
Political stability		0.007**		0.006**		0.007**		0.055**
		(0.003)		(0.003)		(0.003)		(0.025)
Adjusted R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.984	0.984

Robust standard errors clustered at the country-level in parentheses.
*p < 0.10, **p < 0.05, ***p < 0.01

the exports, we utilize the country-level bilateral trade flows, at the four-digit SITC (Revision 1) level from the COMTRADE database from 1992-2019. The higher (lower) level of Theil index refers to the lower (higher) level of diversification.

Figures 1d and 2d suggest that less diversified petrostates' credit ratings have suffered more over time. Whereas in 1992, export concentration had a statistically significant positive effect on oil-dependent states' credit ratings, by 2020, the relationship had disappeared and even turned negative. The effect of export diversification is again stronger for oil-dependent than for oil-abundant petrostates. As Tables A5 and A6 in the supplementary materials show, the effect of diversification on petrostate credit ratings has become especially pronounced since 2010. Whereas pre-2010, a one-unit increase in the Theil index raised oil-dependent and oil-abundant petrostates' credit ratings by 0.296 ($p < 0.05$) and 0.090 ($p < 0.05$), respectively, post-2010, it reduces them -0.273 ($p < 0.05$) and -0.141 ($p < 0.10$). We find similar patterns from semi-parametric kernel smoothing estimations, shown in Figure A7 in the supplementary materials.

We subject these results to a number of additional robustness checks as well.[3] First, we use more restrictive thresholds of oil revenue to code petrostates: at least 20% of GDP or at least 500 USD per capita. The results are broadly consistent with our original findings. We also find that the results do not substantively change when estimating the models using Moody's, Fitch, and S&P's ratings separately.

In addition, we check if the main findings are robust to an alternative coding procedure for sovereign credit ratings. Specifically, we reproduce our main analysis by using an 18-point scale of credit rating scores, proposed by Vu et al. (2020). The findings, presented in Figure A4, remain virtually the same. Hence, we estimate the credit ratings of petrostates and non-petrostates and the marginal effects of oil prices on credit ratings of petrostates and non-petrostates, based on year-level data instead of year-month-level data. The results show that our findings hold (Appendix Figure A5).

Moreover, to further address endogeneity concerns, we employ a dynamic panel data method. Specifically, we estimate the generalized method of moments (GMM) models which provide reliable estimates even in the case of omitted variables (Arellano and Bond 1991; Arellano and Bover, 1995).[4] The GMM estimations also provide similar findings (Appendix Tables A5-A6).

5. QUALITATIVE EVIDENCE

Qualitative evidence from Big Three credit reports lends further support to our quantitative findings. In general, the evidence suggests that credit rating agencies have started to consider "carbon transition risk" as a long-term liability, especially since the signing of Paris Agreement in December 2015 (Fitch, 2021b; Moody's, 2018; S&P Global, 2020a; Volz et al., 2020). S&P, for instance, estimates that, on average, the credit ratings of hydrocarbon exporters in the Middle East will drop by two notches from BBB+ to BBB- by 2040 in their hypothetical stress scenario where the oil price declines by USD 1 per barrel per year and the speed of diversification remains constant from 2012 to 2022 (S&P Global, 2020a).

By and large, however, the evidence suggests that credit rating agencies are not yet punishing petrostates in a way that is proportionate to the long-term risks to their revenue. Fitch,

3. We opt not to present the results in the supplementary materials to maintain brevity. However, the results are available upon request.

4. Monthly oil price, an indicator for petrostates, and the interaction term between these two variables as well as the indicators for months are used as the instruments in the GMM estimations.

for example, points to the uncertain pace of the energy transition as the reason why it has not yet systematically downgraded petrostates "based on climate change stranded asset or broader transition risks" (Fitch, 2021a, p. 13). Moody's and S&P have similarly noted that the energy transition represents more of a risk to petrostate sovereign ratings in the future than in the present (Moody's, 2018; S&P Global, 2017b, 2018, 2019, 2020a). This can help shed light on the relatively small changes in petrostate credit ratings.

However, the evidence does suggest that in recent years petrostates are receiving less of a credit rating boost when oil prices rise and more of a penalty for lack of export diversification. Historically, the evidence suggests that petrostates have benefited from high oil prices (Lee et al., 2017). For example, the upward trend in oil prices in August 2006 was the reason given for an upgrade of Saudi Arabia's credit ratings while sharply lower oil prices led to a downgrade in April 2016 (Fitch, 2016, 2006). However, as Figure 1 shows, petrostate credit ratings did not benefit from either the period of higher oil prices between 2010-2014 nor the temporary resurgence in oil prices in 2018-2019, and initial evidence suggests that the oil price bounce-back of 2021–2022 has not yet had a positive impact. For example, Saudi Arabia's credit rating gradually slipped nearly two grades between the beginning of 2016 and the end of 2019. In 2018, S&P noted that higher oil prices would benefit Saudi balance sheets but that they might prove transient ("Saudi Arabia outlook stable as 'moderate' growth continues to 2021, S&P says," 2018). Similarly, in 2021, Moody's and Fitch both reaffirmed their Saudi ratings despite higher oil prices, citing uncertainty surrounding medium-term oil price forecasts (Bloomberg, 2021).

Additionally, the Big Three point to economic diversification as a buffer to transition risk. According to Moody's, for example, petrostates with relatively low diversification such as Oman, Papua New Guinea, and Saudi Arabia face a rise in external vulnerability while those with (comparatively) more diversified economies, such as the United Arab Emirates and Qatar, face less pressure on their creditworthiness (Moody's, 2018). Fitch similarly notes that diversification can insulate petrostate credit ratings from downgrades (Fitch, 2021a).

In fact, the Big Three credit rating agencies are increasingly accounting for the level of economic diversification in their credit rating decisions on petrostates. For relatively well-diversified petrostates, the agencies tend to acknowledge the contribution of diversification to resilience to external threats such as the prospect of lower-for-longer oil prices. The UAE case also illustrates this point. During 2016, though the Big Three downgraded the credit ratings of numerous petrostates due to low oil prices, such decisions were not made for the petrostates with relatively well-diversified economies such as the UAE. Moody's, for example, confirmed the UAE's rating that September on the expectation that the UAE's economic and fiscal conditions would be resilient even during a period of lower oil prices thanks to its diversified economy (Moody's, 2016). Another notable example is Moody's rating decision on Nigeria's sovereign risk in December 2019. Noting Nigeria's sluggish economic growth, Moody's changed the outlook on Nigeria's ratings from stable to negative but retained its credit rating at B2 due to the increasingly diversified economy (Moody's, 2019b).

On the other hand, less diversified petrostates have often been penalized in their credit ratings. S&P's downgrade of Oman's credit rating to BB- in March 2020, for example, reflects its inability to offset a decline in petroleum income which accounts for about 75% of the government revenues (S&P Global, 2020b). It is also noteworthy that credit rating agencies acknowledge that also high oil prices can accentuate weaknesses in petrostate economies with low diversification. According to Fitch, for example, higher oil prices could weaken Saudi

Arabia's commitment to diversify its economy, which in turn would pose greater and more widespread credit challenges (Nereim, 2017).

On the whole, then, the qualitative evidence is consistent with the quantitative results. While the Big Three have given little indication that they are systematically penalizing petrostate credit ratings due to concerns about the impact of the energy transition on petrostate economies, the evidence nevertheless suggests that transition risks may be imposing a ceiling on petrostate credit ratings, such that factors that might have previously resulted in ratings upgrades—like higher oil prices—are not having the same effect. This is consistent with our quantitative findings, which suggest a slight, gradual decline in petrostate credit ratings rather than a steep one. Similarly, there is evidence that energy transition risks are causing agencies to ascribe greater weight to diversification in their assessments of petrostates.

6. DISCUSSION AND CONCLUSION

The evidence suggests that rating agencies have gradually started weighing stranded fossil fuel asset risks in their assessments of petrostate credit ratings. The effects we find are still small, however. After controlling for economic fundamentals and oil prices, the average petrostate credit rating has dropped less than one-tenth of a grade since the 1990s, mostly since 2010, and qualitative evidence confirms that the Big Three rating agencies still largely treat the energy transition as an influence on future rather than current ratings.

However, there is evidence that rating agencies are beginning to shift. While our quantitative results do not represent causal estimates, they nevertheless offer suggestive evidence that petrostates' ratings are buoyed less by high oil prices and more by export diversification in recent decades than in previous decades, while the qualitative evidence similarly suggests that rating agencies are paying increasing attention to petrostate diversification prospects and even see high oil prices as a potential liability insofar as it discourages further efforts to diversify.

Our findings are broadly consistent with previous speculation that the Big Three rating agencies have not yet adjusted petrostates' credit ratings in line with the energy transition's likely long-term impacts on petrostate economies. Nevertheless, the evidence suggests that petrostates have not been completely spared from the effects of concerns about energy transition risks. Concerns about lack of progress in economic diversification and stranded asset risks appear to be having a modest ceiling effect on petrostate credit ratings. Nevertheless, the findings indicate that petrostate credit ratings do not yet reflect the real economic headwinds these countries will very likely face in the coming decades. This is by design; credit rating agencies largely rely on present indicators to produce assessments of short-to-medium term risk, whereas the energy transition represents an uncertain, long-term risk not yet indicated in present conditions. While the Big Three agencies recognize energy transition risks, all of them still view these risks as too uncertain and long-term to impact credit ratings in the present.

The challenge, then, is twofold. The first is the inherently uncertain timeline and severity of the energy transition's effects. The second is that Big Three rating methodologies are not well-suited to incorporating risks whose onset is predictable but whose timeline is not. While rating agencies cannot control the former, they can nevertheless attempt to adapt their ratings to account for this new class of risks. This would not necessarily entail completely revamping their methodologies. Rather, agencies could publish separate grades for long-term transition risks. All three major ratings agencies have published reports on energy transition risks for fossil fuel producers in recent years, noting that there is variation in how exposed different producers are based on factors like economic diversification and fossil fuel dependence, but have fallen short of assigning concrete grades.

Notably, these results cover a period that includes only the early days of the renewable energy transition. The uptake of renewable energy and electric vehicles has consistently outstripped forecasts (Van de Graaf and Bradshaw, 2018) and may continue to grow exponentially. As the time horizon for the energy transition's effects become clearer, petrostates – and their credit ratings – may reach a tipping point, with steep and sudden downgrades. This is likely to be especially challenging given that petrostates have historically borrowed at low rates on the expectation of future oil revenue (Nooruddin, 2008). Moreover, because rating agencies base their grades so heavily on current and recent indicators, credit rating downgrades may not provide petrostates much warning before declining demand constrains government revenues. In the coming years, then, petrostates may face a perfect storm: flatlining or declining demand, reduced revenue, *and* reduced ability to borrow.

Petrostates may be able to mitigate the negative effects of the transition by using present windfalls to adapt proactively – for example by investing in education and new industries to diversify their economies. Existing research on this front, however, is not encouraging, as recent studies suggest that most resource-rich countries have diversified less over the past several decades than resource-poor countries (Lashitew et al., 2021; Ross, 2019). The reasons for this are numerous and varied and range from the influence of vested interests in the fossil fuel sector, to governments' reliance on the provision of patronage and generous welfare states using rents for political survival, to the disincentives that a large public sector with safe, well-paying jobs generates for taking risks in the private sector (Cherif et al., 2016; Hvidt, 2013). However, the risks of stranded assets and declining government revenue posed by the energy transition may provide new impetus for diversification among petrostates. Future research could thus identify the conditions and strategies that make diversification more likely to be realized.

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