# Stranded Fossil Fuel Reserves and Firm Value*

by

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Do capital markets reflect the possibility that fossil fuel reserves may become "stranded assets"? We document that while oil reserves are an important component of oil producers' value, reserves growth has a negative effect. This negative effect is stronger for producers with higher extraction costs and for reserves located in countries with strict climate policies. When we decompose reserves into developed and undeveloped, we show that the negative effect of reserves growth on value is due to firms growing their undeveloped reserves. Our evidence is consistent with markets penalizing future investment in undeveloped reserves growth due to climate policy risk.

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Abstract:

Do capital markets reflect the possibility that fossil fuel reserves may become "stranded assets"? We document that while oil reserves are an important component of oil producers' value, reserves growth has a negative effect. This negative effect is stronger for producers with higher extraction costs and for reserves located in countries with strict climate policies. When we decompose reserves into developed and undeveloped, we show that the negative effect of reserves growth on value is due to firms growing their undeveloped reserves. Our evidence is consistent with markets penalizing future investment in undeveloped reserves growth due to climate policy risk.

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"…. according to Carbon Tracker, a think-tank, more than half the money the big oil companies plan to spend on new fields would be worthless in a world that halved emissions by 2030." *The Economist, September 21st, 2019*

"Stranded assets" are assets at risk of becoming obsolete from unanticipated or premature write-offs, downward revaluation or being converted to liabilities due to regulatory or environmental changes. In this paper, we examine whether the market valuation of firms owning fossil fuel reserves reflects the risk that these assets may become stranded in the transition to a low-carbon economy. This question is of critical importance as many financial institutions and regulators have identified the mispricing of stranded asset risk as a potential systemic risk and threat to financial stability.

Recent developments have hit the energy markets hard. Oil producers, in particular, have had to deal with the catastrophic consequences of the oil price war between Saudi Arabia and Russia, the collapse in oil demand caused by the coronavirus pandemic, and the unprecedented negative prices as storage space has disappeared. Although not in the context of environmental changes, the global shocks caused by these events have made the importance and severity of stranded asset risk more apparent than ever.

In this paper, we focus on North American oil producers and their reserves for several reasons. First, the stock market for oil firms' equities as well as the market for crude oil and other oil products are very liquid. The markets for coal products and coal firms' equities, on the other hand, are more fragmented and less liquid, with the markets for natural gas in-between. Second, North American oil producers face low domestic political risk, and foreign exchange exposure. These firms are also subject to stringent regulation and monitoring unlike firms in other countries that are traded in markets that are often fragmented, illiquid, and vulnerable to manipulation.[1] Finally, conventional oil production has now peaked and is on a long-run global decline. Recent technological advances, however, have reshaped oil production in North America by transforming uneconomical and inaccessible resources into viable large-scale unconventional plays. These unconventional oils are more difficult and costly to exploit than conventional deposits and require new, highly energy (carbon) intensive production

[1] Companies, such as the Brazilian Vale and the Russian Lukoil, are stark examples where bad corporate governance, a spike in political risk and currency weakness have had a huge impact on market valuations.

technologies.[2] [3] According to Rystad Energy, there are about 264 billion barrels of recoverable oil reserves (the most likely estimate for existing fields, discoveries and as-of-yet undiscovered fields) in the United States and 167 billion barrels in Canada. According to scientists (e.g. McGlade and Ekins, 2015), if these reserves were exploited, the resultant emissions of $CO_2$ would correspond to an increase in atmospheric greenhouse gases beyond the threshold above which we risk a global extinction event.

Since the early 1990s, scientists have warned of the negative environmental impact of increasing atmospheric carbon dioxide concentrations due to human activity (see Santer, 1995). Over the last decade, institutional investors too have drawn attention to the risk of fossil fuels becoming stranded as a result of adhering to a 2°C carbon budget.[4] This carbon budget specifies the maximal amount of cumulative carbon emissions that can be emitted without exceeding a 2°C increase in temperature above the preindustrial levels. In the United Nations Climate Change (UNCC) 2015 Paris agreement, world governments confirmed their intention to limit global warming "well below 2°C above pre-industrial level" and pursue efforts to "limit the temperature increase to 1.5°C". The 2018 report of the International Energy Agency (IEA) suggests that to have any chance of hitting the 2°C target requires drastic and immediate cuts in the use of fossil fuels. Instead, data from the Global Carbon Project (2019) show that output from fossil fuels have grown by around 2.7% in 2018, the largest increase in seven years. This increase in $CO_2$ emissions leaves the world far from the trajectory needed to meet global climate goals. Oil producers are therefore heavily exposed to the risk of being unable to burn all their reserves when climate policy becomes more ambitious.

In this paper, we document that while total proved reserves are an important component of oil producers' value, the growth of these reserves is penalized by the market.[5] Oil

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[2] According to the Energy Information Administration, 49% of all U.S. crude oil proved reserves are in shale oil and 96% of Canada's proved reserves are in oil sands.

[3] Pembina Institute (2017), an Alberta-based environmental group, reports that oil sands greenhouse gas emissions intensities are between 14% and 37% per cent higher than conventional crude oil. Shale oil, on the other hand, is responsible for methane leakage (partly through deliberate venting). For shale oil to be more "climate-friendly" than coal, there should be no more than 3% leakage. According to the National Oceanic and Atmospheric Administration (NOAA) and University of Colorado (2017) report, the leakage is between 4% and 9%.

[4] Financial services companies such as HSBC picked up on the 2011 report by the Climate Tracker Initiative on "Unburnable Carbon - Are the World's Financial Markets Carrying a Carbon Bubble?".

[5] The U.S. Securities and Exchange Commission (SEC) uses the term "proved reserves" for oil and gas and "proven reserves" for coal reserves. Proved oil reserves are the estimated quantities of oil that, with reasonable certainty, are recoverable under existing economic and operating conditions. These estimates are based on available geologic and engineering data.

reserves are found in geologic formations known as fields that lie beneath the earth's surface, and oil production companies extract these reserves for processing and sale. Oil is usually recovered (extracted) by drilling wells. Drilling is an up-front investment in future production. Drilling costs depend on depth, increasing roughly exponentially and ranging from a few hundred thousand dollars for a relatively shallow well to millions of dollars for a very deep well. The investment is irreversible since once drilling is complete, the costs are almost completely sunk. In this paper, when we decompose total reserves into developed and undeveloped, we show that the positive effect of reserves on firm value is due to the amount of developed oil reserves and the negative effect is due to the growth of undeveloped oil reserves. The distinction between developed and undeveloped proved oil reserves is that the former are reserves which are extracted from existing wells while the latter are classified as reserves from new wells on undrilled acreage or existing wells where a major capital expenditure is required for completion[6].

Both developed and undeveloped reserves are treated as assets for the oil producer, so they should have a positive (or at least non-negative) effect on their value.[7] Recent events, however, have demonstrated the risky nature of fossil fuel reserves. On April 20th, 2020, West Texas Intermediate crude for May delivery settled at negative $37.63 per barrel, meaning producers were paying traders to take the oil off their hands. This is a stark example of stranded asset risk, i.e. an unexpected demand shock can not only erase the value of these assets but turn them into liabilities.

Our results suggest that even before the COVID 19 pandemic, capital markets priced stranded asset risk to a certain extent. We show that oil firm valuation was increasing only in reserves that were already developed while the growth (and thus the future investment in exploration and development) of undeveloped oil reserves had an economically and statistically

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[6] Before 2010, the U.S. Securities and Exchange Commission, allowed only proved reserves to be publicly reported. After 2010, firms can also report probable and possible reserves. Probable reserves are reserves that have an estimated confidence level of approximately 50% of being successfully recovered. Possible reserves are those with only 10% estimated probability of recovery. The SEC requires the lower probability of recovery to be verified by a third party before an oil company can publicly report probable and possible reserves to potential investors.

[7] Oil reserves are by far the most important assets that oil firms own. Financial analysts and investors pay great attention to information related to reserve changes released from these companies. For example, when the Swedish oil company Lundin announced a significant discovery of oil and gas the Norwegian continental shelf in 2011, their share price appreciated more than 30% in one day. In January 2004, when Shell announced a 28% downward revision of their proved oil reserves, their share price fell 12% over the 3-4 weeks following the announcement.

significant negative effect on oil producers' value. In particular, one standard deviation increase in the growth of undeveloped reserves decreased firm value (Tobin's *Q*) by about 2.6%. This negative effect was stronger for oil producers with higher extraction costs. Our results are consistent with the recent major write downs in the Canadian oil sands undeveloped reserves where companies cut back on their development plans because of the higher extraction cost. In 2017, ConocoPhillips and ExxonMobil each wrote down more than 2 billion barrels of their previously proved undeveloped tar sands reserves.[8]

To examine further the effect of stranded assets risk on firm value, we hand collect data on oil reserves locations from the companies' annual reports. We show that the negative effect is stronger for oil producers with large undeveloped reserves in countries with strict climate policies. We also interact the growth in undeveloped reserves with an indicator variable for the period after the 2015 Paris climate agreement to examine if there has been a change in the sensitivity of firm value to undeveloped oil reserves growth. Our empirical results provide support for a much stronger negative effect of undeveloped reserves growth following the 2015 Paris agreement. Overall, our evidence is consistent with capital markets penalizing firms' investment in undeveloped reserves growth due to climate policy risk. The markets seem to take into consideration, at least partially, that while these reserves require substantial capital expenditures to be developed, they might never be utilized.

We show that our main results remain the same when we carry out several robustness tests. Our results do not change when we use alternative measures of firm value and oil reserves. We also confirm our main results for a subsample of US firms only as well as for a subsample of all firms traded on US stock exchanges (this includes all Canadian firms cross-listed in the US). Focusing on these sub-samples of firms allows us to carry out a cleaner test of our main findings as US firms face more stringent reporting and regulatory requirements and trade in equity markets that are much bigger, less segmented, and more liquid. For the US firms and the cross-listed Canadian firms, we collect additional data on institutional ownership, analysts' coverage, and stock liquidity. We examine the effect of these variables on the validity and strength of our results. Institutional investors are influential shareholders who could alter the information and trading environment of a firm and therefore affect its value. Similarly,

[8] At the end of each year, oil companies must report proved reserves to the U.S. Securities and Exchange Commission (SEC). The SEC allows companies to classify undeveloped reserves as proved if the company has a development plan for drilling those reserves within five years of being booked.

increase in analysts' coverage could result in reduction in information asymmetry and/or increase in monitoring activities. This can influence firm's stock market liquidity and therefore its value.

Our results show that institutional ownership does not explain or change the negative effect of undeveloped oil reserves growth on firm value. Prior evidence on the effect of institutional investors has been mixed. Several studies have documented that investors are already considering climate change risks as relevant. For example, Krueger, Sautner and Starks, (2019) document that larger long-term, and environmental, social and governance (ESG)-oriented investors actively manage their climate risk exposure (e.g. analyzing portfolio firms' carbon footprints and stranded asset risks). Krueger et al (2019), however, show that perceived overvaluations of fossil fuel firms are not large and that most investors do not consider divestment as the most effective approach for addressing climate risks. Similarly, Bolton and Kacperczyk (2020) find that divestment effects from large investors do not generally explain the carbon risk premium that they document.

Our results remain unchanged when we include analysts' coverage and stock market liquidity in our regression analysis. We show that neither analyst coverage nor stock market liquidity changes the relation between the growth of undeveloped oil reserves and the decrease in firm value. Finally, in all our regression specifications, we control for all the variables that have been shown to affect firm value as well as include year fixed effects to ensure that the results are not driven by the developments of the underlying commodity price, and in particular the large drop in oil prices after 2014.[9]

We believe our paper is the first to show that while reserves are an important component of oil firm value, the growth of these reserves has a negative effect on firm value. We contribute to several strands of the literature. First, our paper is related to the literature on the so-called "carbon bubble". Carbon Tracker Initiative (2013) provided the first estimate of the amount of stranded fossil fuel reserves of listed firms based on the 2°C global carbon budget from 2000 to 2050.[10] Despite the large proportion of potentially unusable "stranded" reserves, oil companies continue to invest predominantly in locating and developing new

[9] We estimate all specifications using the (logarithm of) crude oil price and year dummies to control for time fixed effects. In a robustness test, we show that our results remain the same when we use changes and volatility of oil prices instead of logarithm of oil price.
[10] The value of global financial assets at risk from climate change has been estimated at US$2.5t by Dietz, Bowen, Dixon & Gradwell (2016) and US$4.2t by the Economist Intelligence Unit (2015).

reserves. Previous studies have failed to document a negative market reaction to these large exploration expenditures. This fact has prompted academics and policy makers to argue that financial markets might carry a "carbon bubble" where assets in fossil fuels are currently overvalued given the future requirement to drastically reduce carbon emissions. Weyzig, Kuepper, van Gelder, and van Tilburg (2014), for example, study the exposure in high-carbon assets of 43 of the EU's largest banks and pension funds. They conclude that to minimize potential "carbon bubble" related losses, governments should pursue firm policy that leads to quick transition to a low-carbon economy.

Our paper also contributes to the literature that studies the pricing implications of climate risk (see, e.g., Andersson, Bolton, and Samama (2016), Daniel, Litterman, and Wagner (2019), or Litterman (2013)), and the uncertainty about climate change policies (see Freeman, Wagner, and Zeckhauser (2015)). HSBC's (2013) report is the first attempt to estimate the value-at-risk (VaR) from stranded assets for six of the largest oil producers. The study shows that, although not directly related to unburnable carbon, a moderate reduction in the demand for oil that lowers oil prices could result in potential value at risk of 40% to 60% of oil producers' market cap. Ilhan, Sautner and Vilkov, (2019) show that climate policy uncertainty is priced in the option market. Specifically, the cost of option protection against tail and variance risks is larger for more carbon-intense firms. Batten, Sowerbutts, and Tanaka (2016) analyze stock market reaction to climate change news in an event study for the period 2011-2016. They examine the effect of news which contains the words "carbon bubble", "unburnable carbon", or "fossil fuel divestment". They find a positive and significant effect on the abnormal return for renewable energy companies, and a negative but insignificant effect on the abnormal return of oil and gas companies. The authors argue that the insignificant effect is the result of investors' having difficulties assessing future climate policies and their long-run risks for fossil fuel companies. In a similar spirit, Byrd and Cooperman (2016) use events announcements concerning developments in the Carbon Capture and Storage (CCS) technologies for the period 2011 to 2015. They find a positive and significant effect for news on breakthroughs in CCS developments. Setbacks in CCS development, however, have a negative but insignificant effect on the abnormal returns of fossil fuel companies. The authors interpret this as evidence that, either investors have already priced in the potential risk of climate-related stranded fossil fuels, or investors believe that governments would never limit the production of fossil fuel.

Recent asset pricing models have also highlighted the importance of climate risks as a long-run risk factor. For example, Bansal, Ochoa, and Kiku (2017) study the welfare implications of rising temperature and propose a temperature-augmented long-run risks model that accounts for the interaction between temperature, economic growth, and risk. Bolton and Kacperczyk (2020) and Hsu, Li and Tsou (2019) highlight the importance of carbon risks and environmental pollution in the cross-section of stock returns. At the firm level, Addoum, Ng, and Ortiz-Bobea (2019) show that extreme temperatures can adversely affect corporate earnings and Kruttli, Tran and Watugala (2020) show that extreme weather is reflected in stock and option market prices. Ginglinger and Moreau, (2019) provide evidence that suggests that after the Paris Agreement, greater climate risk leads to lower firm leverage with firms decreasing their demand for debt and lenders reducing their lending to firms with the greatest risk. Overall, there is growing evidence indicating that climate risks may be priced in financial markets. Hong, Li, and Xu (2019) show that prolonged droughts forecast both declines in profitability ratios and poor stock returns for food companies. Similarly, Kumar, Xin, and Zhang (2019) find that stocks with higher climate sensitivity forecast lower stock returns and firm profits.

Finally, our paper is related to the literature accessing the financial effects of environmental regulation. The risk of stranded fossil fuel reserves and climate change risks in general are no longer considered to affect only future generations.[11] A survey of institutional investors attitude towards climate change reveals that a large fraction of investors considers climate change risks (especially transition risks) as already present and believe these risks will materialize within the next five years (Krueger, Sautner, and Starks, 2019).

The remainder of this paper is as follows. Section 2 motivates the paper and discusses the context of our research questions. Section 3 discusses the sample data and presents summary statistics. Section 4 describes our research design and Section 5 presents the results of the paper. Section 6 concludes.

[11] In addition, the anticipated spike in temperatures will not affect the world evenly. Studies show that productivity peaks when temperatures average 55°F (13°C), meaning global warming may increase productivity in the northern countries while having devastating effects on the tropical countries, i.e. climate change could worsen world-wide inequality.

## 2. Background to the study

For the past few centuries, economic growth has involved the accumulation of fossil-fueled capital, such as coal power plants and gasoline-fueled vehicles which release greenhouse gases (GHG) to the atmosphere. To prevent the resulting climate change that precipitates the risk of extreme drought, wildfires, floods, and food shortages for hundreds of millions of people, all countries must reduce emissions to near-zero levels (IPCC, 2014). Such transition implies moving from production based on fossil fuel capital to production based on carbon-neutral capital. Most economists agree that the optimal policy to enforce such a transition is to use a carbon price, imposed through a carbon market or, perhaps preferably (Goulder and Schein, 2013), a carbon tax.[12] Combined with targeted innovation policies, a carbon price could redirect investment away from polluting and towards clean capital at a relatively low cost (IPCC, 2014). In this context, calls for a global carbon price in the order of $40 to $80 dollars per ton of $CO_2$ appear increasingly plausible (Stiglitz et al., 2017).

Following the 2015 Paris Agreement, the number of jurisdictions pricing carbon has increased substantially to a coverage of about 20 % of global greenhouse gas emissions (World Bank, 2019). Many financial institutions, however, have warned that an abrupt and coordinated increase in carbon prices could cause a major shock to the stock market, with the potential for systemic risk. For example, Bank of England's governor expressed strong concerns for the potential role that stranded assets could play in destabilizing the global economy (Carney, 2015). Since 2016, the European Systemic Risk Board (ESRB), an agency of the European Central Bank, considers the abrupt implementation of strict climate policy (defined as "hard landing") as part of the systemic risks to the global financial system (ESRB 2016).[13] Their main concern is the enormous reserves of fossil fuels that would need to remain in the grounds, but which are currently on the fossil fuel companies' balance sheets. If there is a collapse in asset valuations, the initial shock that climate policy would create by forcing the obsolescence of large fossil fuel assets could trigger systemically relevant effects. ESRB's policy recommendations include the mandatory disclosure of carbon intensity by some firms as well as

[12] The quintessential example is British Columbia's carbon tax, which adds C$30 per metric ton to fossil fuels sold and combusted in the province (which account for over 70 percent of its total greenhouse gas emissions). It is generally accepted that the tax is reducing emissions in British Columbia without harming the provincial economy.

[13] The risk of hard landing is the risk of late transition to a low-carbon economy, where governments will suddenly have to take drastic actions.

the inclusion of climate-related prudential risks in stress tests (leading to "climate stress tests") and other macroprudential strategies.

Despite the large fraction of potentially stranded reserves, fossil fuel companies themselves find it "highly unlikely" that carbon emissions would be cut to reach the 2°C target by 2050 (Exxon Mobil, 2014).[14] In addition, the largest fossil fuel firms have argued that carbon capture and sequestration (CCS) technology will become sufficiently affordable, therefore more of current fossil fuel reserves can be burned without exceeding the carbon budget. Caldecott, Kruitwagen, and Kok (2016), however, find that the slow deployment and high cost of CCS make it very unlikely that the IPCC scenarios for wide-spread full-capacity CCS will be met.[15] Based on a cost comparison by Rubin, Davison, and Herzog (2015), CCS technology costs as much (and possibly more) in 2015 as it did in 2005. In contrast, wind levelized cost of energy (LCOE) has decreased by 61% from 2009 to 2015 and utility-scale solar LCOE has decreased by 82%.[16][17] Lazard's (2017) LCOE calculations show that utility-scale solar photovoltaic (PV) and wind energy have become cheaper than nuclear, coal, and even natural gas combined cycle.[18]

Nevertheless, Shapiro (2020) documents that in most countries, import tariffs and non-tariff barriers are substantially lower on dirty industries than on clean industries, where "dirtiness" is defined as the $CO_2$ emissions per dollar of output. This difference in trade policy creates a global subsidy to $CO_2$ emissions in internationally traded goods and therefore contributes to climate change. The paper estimates that this global implicit subsidy amounts to several hundred billion dollars annually. The industry's location or "upstreamness" in the

[14] Recent lawsuits against oil giants such as BP, Chevron, Conoco-Phillips, ExxonMobil and Royal Dutch Shell, have highlighted claims that these companies have known for some time about the consequences of global-warming gases generated by burning fossil fuels, but sought to obscure them.
[15] The think tank Ceres estimates that $12.1 trillion are needed as investment in new clean power generation over the next 25 years to limit climate change to 2°C.
[16] The levelized cost of energy (LCOE) is an economic measure of the average cost to build and operate a power-generating asset divided by energy output of this asset over its lifetime. The measure is the minimum price at which electricity generated by the asset must be sold to break-even. LCOE is often cited as a convenient summary measure of the overall competitiveness of different generating technologies.
[17] Utility-scale solar refers to large scale electricity generation either through a photovoltaic power or through concentrated solar power. The utility-scale solar sector has led the overall U.S. solar market in terms of installed capacity since 2012.
[18] The nuclear fuel cycle, for example, starts with exploration for uranium and the development of mines to extract uranium ore and ends with highly radioactive material that must be removed and stored under water at the reactor site in a spent fuel pool for several years. The natural gas combine cycle is currently the most economical of all conventional energy sources.

global value chains accounts for a large share of the correlation between CO2 intensity and trade policy. i.e. more upstream industries have both lower protection and greater emissions. One explanation for this correlation is lobbying competition. Firms may lobby for high tariffs on their own outputs, but also lobby for low tariffs on the goods they use as inputs. Because final consumers are poorly organized, politicians give the least protection to the upstream (the dirtiest) industries and the greatest protection to the downstream (the cleanest) industries.

Along the same line, Yergin and Pravettoni (2016) reject the existence of a carbon bubble for fossil fuel companies. They argue that 80% of the market capitalization for large oil companies reflects short to medium-term reserves (i.e. reserves that will reach the market in five to ten years), whereas the transition to renewable energy may take decades[19]. With strong advocates arguing for and against the likelihood of fossil fuel reserves becoming unburnable, investors may find it difficult to confidently embed carbon risk into fossil fuel companies share prices. With widespread growth in passive portfolio management in diversified indexes that includes a large weighting for fossil fuel stocks, institutional investors may also be unable to divest fossil fuel corporation stocks to reduce their stranded asset risk. Similarly, active portfolio managers may fear lower returns relative to market benchmarks as performance goals (see, e.g. Gilbert 2015). This paper examines whether (and when) capital markets have recognized the potential loss of value to oil companies due to unburnable fossil fuel reserves.

## 3. Sample Data and Summary Statistics

We begin with the universe of publicly traded firms in the COMPUSTAT supplement Industry Specific: Oil & Gas dataset for the period 1999 to 2018[20]. The dataset contains annual firm-level data on developed and total proved oil reserves, oil production and exploration costs. We obtain accounting data and annual share price data for each firm from COMPUSTAT Fundamentals, and data on analyst coverage and ownership data for US firms are from Thomson Reuters. Daily stock prices and volume data are from CRSP.

Figure 1 presents the distribution of firms and the annual average crude oil price for each year of the sample period. Over 37% of the firms in the initial sample become inactive

[19] Based on a survey of industry analysts, a 2017 report ominously titled "All Swans are Black in the Dark" found that equity research firms generally "only look at the next five years" to incorporate risk considerations. This creates systematically mismatched time horizons between risk considerations and sources of stranded reserves risks.

[20] Prior to 1999, the data on oil reserves in COMPUSTAT Industry Specific: Oil & Gas have very low coverage.

during our sample period with almost a third of them after the sharp decline in oil prices in 2014. Anderson, Kellogg, and Salant (2014) show that once the investment to drilling is made, firms do not alter production rates or delay production due to oil price changes: the shape of the production profile is consistent throughout the data, including the periods when the price of oil was very low. This profile is consistent with a production technology in which production rates are constrained by geologic characteristics of the oil reservoir such as its pressure, the remaining volume of oil near the well, and rock permeability.

Table 1 provides the distribution of firms by country together with firm-level book and market-to-book (Tobin's Q) value of assets, market leverage, capital expenditures and total proved reserves for each country (averaged by firm and year) as well as country-level total proved oil reserves (averaged by year).[21] Most of the firms in the COMPUSTAT Industry specific dataset are North American oil producers with majority being small companies as shown by the average value of total assets and barrels of total proved oil reserves. As discussed in the introduction to this paper, we eliminate all firms that are not incorporated in the US or Canada.

We apply the standard filters to clean the data. We drop all observations for which data on total and developed reserves, total assets, capital expenditures, long and short-term debt and shares outstanding and stock price are missing. We also remove all royalty trusts and asset management companies, utilities as well as subsidiaries, private firms, and LBOs. We remove all penny stocks and all companies that have had only negative book equity during our sample period. The final sample consists of 600 US and Canadian oil producers for the period 1999 to 2018. We hand collect data on the location of both developed and undeveloped proved oil reserves from the companies' annual reports for each firm-year of our sample.

Panel A of Table 2 presents summary statistics for our sample firms. The average firm has around $5.6 billion USD in total assets. The median firm, however, is small with just over $350 million in total assets. The average (median) Tobin's Q value is 2.63 (1.08). Compared to the average firm in the COMPUSTAT Fundamentals database, the average firm in our sample has similar mean (median) market leverage 27% (21%) but unlike firms in the COMPUSTAT universe, on average (for the median firm) almost 72% (97%) of this debt is long-term. The

[21] The sample also does not cover several international firms with very large oil reserves as they are not publicly traded companies. For example, Saudi Arabian Oil Company, whose total proved oil reserves exceed 200 billion barrels, is fully owned by the government of Saudi Arabia.

median firm in our sample has large capital expenditures, 21.20% of book assets, compared to the COMPUSTAT universe average of 2.63%. Finally, the average (median) firm in the sample has 0.044 (0.023) barrels of oil per dollar of total assets.

In panel B of Table 2, we illustrate our idea in a simple way. Panel B shows the financial characteristics of the sample firms with high (top quartile) and low (bottom quartile) levels of total reserves and high and low growth in total reserves. Not surprisingly, the large firms in our sample have large levels of total proved reserves and therefore higher valuations. However, firms with higher reserves growth have significantly lower Tobin's Q than firms with low total reserves growth. These firms also have higher leverage and capital expenditures than firms with low reserves growth. The next section provides more context to this idea and discusses the research design for our study.

## 4. Research Design

### 4.1. Empirical Specifications

We use the standard measure of firm value, Tobin's Q, calculated as the sum of the market capitalization of the firm's common equity, the liquidation value of its preferred stock, and the book value of its debt divided by the book value of assets. To test the link between oil reserves and firm value, we estimate the following general form panel regression model:

$$ln(Q_{it}) = \alpha_i + \beta_1 Reserves_{it} + +\beta_2 Res\ Growth_{it} + \beta_3 Controls + \varepsilon_{it} \tag{1}$$

where *Reserves* is calculated as oil reserves in barrels scaled by firm's total assets, i.e. the unit is barrels per US dollar of total assets and *Res Growth* is the percentage change in oil reserves $\left(\frac{Reserves_{i,t} - Reserve\ \ _{i,t-1}}{Reserves_{i,t-1}}\right)$. First, we use the amount of total proved reserves, then we split total proved reserves into developed proved reserves (*Developed*) and undeveloped (total-developed) proved reserves (*Undeveloped*).[22] To get the most comprehensive data, we only consider the amount of proved oil reserves and do not include possible or probable reserves.[23] Table A1, in

[22]We also estimate the dollar amount of total as well developed and undeveloped proved reserves by multiplying the number of barrels by the average oil price per barrel sold and then scale them by total assets. The results remain the same.

[23] Proved oil reserves are "the estimated quantities of oil, which, by analysis of geoscience and engineering data, can be estimated with "reasonable certainty" to be economically producible from a given date forward, from

the Appendix, provides the definitions of all variables used in the study. Regression specification (1) captures the relation between the level and growth of total proved oil reserves and firm value as well as the separate effect of developed and undeveloped reserves. For all regression specifications, we cluster standard errors at the firm level and include firm-year fixed effects.

The dependent variable in most of our analysis is *lnQ* (the natural logarithm of Tobin's *Q*) rather than *Q*. Amihud, Schmid and Solomon (2017) show that the regression model fits the data much better with *lnQ* as the dependent variable compared to *Q*.[24] Other researchers use *lnQ* when studying the effects of some variables on firm value. For example, Sanders and Block (2011) show that the effect of intangible capital (measured by R&D expenditures, patents and trademarks) on firm's value, is best explained in a model where the dependent variable is *lnQ*. We carry out several robustness checks, where we estimate specification (1) using Tobin's *Q*, the annual market-to-book ratio of equity (MTB) or the market capitalization in line with studies in the accounting literature. Our results remain unchanged.

When we estimate regression specification (1), we control for all the variables that (as previous studies have shown) might affect firm value. The control variables are as follows. We include market leverage defined as total book value of debt divided by equity market cap plus total book debt. Size is the log of beginning of year total assets and profitability is defined as the earnings before interest, taxes, depreciation, and amortization scaled by lagged assets. The effect of profitability on Tobin's Q is ultimately an empirical issue as on one hand more profitable firms may have more favorable investment opportunities, leading to higher valuations. On the other hand, high levels of cash flow may also signal that the firm is in a mature phase and has limited growth opportunities.

We also include capital expenditures divided by beginning of year (lagged) total assets as a more direct measure of firms' investment opportunities, i.e. the investments that the firm undertook. Firms that invest more likely have higher growth opportunities that should translate into a higher Q value. We also include dividends calculated as the dividends paid in the year divided by lagged assets. On one hand, this variable may capture the effect of capital constraints. Alternatively, firms that pay dividends may have more free cash flow, which may

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known reservoirs, and under existing economic conditions, operating methods, and government regulations" (US Security and Exchange Commission-SEC).

[24] The logarithmic transformation makes lnQ have a smaller positive skew and smaller deviation from the normal distribution than that of Q.

potentially be used to overinvest in marginal or even negative NPV projects such as the acquisition or exploration of undeveloped oil reserves. Shareholders may value high dividends as they will mitigate such agency costs. All these controls have been used in previous studies, e.g., Allayannis and Weston (2001), Carter, Rogers, and Simkins (2006), Roll, Schwartz and Subrahmanyam (2007) and Bolton, Chen and Wang (2011). All regression specifications contain year dummies (and the logarithm of oil price) for the period 1999 to 2018 to ensure that our results are not driven by the large drop in oil prices after 2014.

Next, we examine the effect of costs on the relation between oil firm value and its reserves. The possible shift to a low-carbon economy will require a dramatic change in the current growth model for oil producers. Carbon Tracker's (2019) reports shows that no new oil sands projects fit within a Paris-compliant world. Despite this, in 2018 ExxonMobil approved capital expenditures of $2.6bn for the Aspen oil sand project. US shale specialists also have portfolios that are entirely out of the permissible carbon budget.[25] We argue that oil producers with higher extraction costs will face higher risk of stranded assets as firms will develop first the reserves with the lowest extraction costs. To analyze this issue, we estimate the following regression model:

$$\begin{aligned} ln(Q_{it}) = \alpha_i + \beta_1 Reserves_{it} + \gamma_1 Reserves_{it} \times Cost_{it} \\ + \beta_2 Res\ Growth_{it} + \gamma_2 Res\ Growth_{it} \times Cost_{it} + \beta_3 Controls + \varepsilon_{it} \end{aligned} \quad (2)$$

where *Cost* is a proxy for extraction costs calculated as the average annual operation costs per barrel of annual oil production for firm *i* in year *t*.[26] The control variables are the same as in regression specification (1).

We also carry out a battery of robustness tests. First, we estimate regression specification (1) for the sub-sample of US firms. We also collect additional data for the US traded firms in our sample that allows us to carry out several tests. We examine the effect of institutional ownership, analyst coverage and stock market liquidity on the validity and

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[25] In 2018 and 2019, all the major oil companies approved projects that fall outside a "well below 2 degrees" budget on cost grounds. These will not deliver adequate returns in a low-carbon world. Examples include Shell's $13bn Canada LNG project and BP, Total, ExxonMobil and Equinor's Zinia 2 project in Angola and BP, Chevron, ExxonMobil and Equinor's project in Azerbaijan (see Carbon Tracker (2019) for more details.).

[26] For example, the *Cost* measure for Hess was around $37 per barrel in 2018. Hess produced 101 million barrels of oil equivalent (MMboe) and had $3,780 million in total operating expenses.

strength of our results. Institutional investors are influential shareholders who can alter the information and trading environment of a firm and therefore affect its value. In recent years, the percentage of institutional ownership has increased significantly.[27] The institutional investors' choice to increase their holdings of a company might be a valuable signal affecting the decisions of not only the management of the company but also of analysts and individual investors. We estimate the effect of institutional ownership, analysts' coverage, and stock market liquidity in separate regressions as they are highly correlated. Previous studies have examined the effects of institutional ownership on firms' information and trading environment. For example, Boone and White (2015) show that higher institutional ownership is associated with greater management disclosure, analyst following, and liquidity, resulting in lower information asymmetry. In contrast, Kadach and Schain (2016) document a negative effect of institutional ownership on analysts' coverage.

In addition, some activists' institutional investors have urged divestment of coal and oil and gas firms. In 2017, Norway's $1 trillion sovereign wealth fund started work on the divestment of holdings in international petroleum companies. The World Bank committed to no longer be lending money for oil and gas exploration. Some University endowment funds, such as Harvard, have also approved divestment from fossil fuel firms. Recent research, however, suggests that it is unlikely that current or previous divestment campaigns have produced any substantial effect on firm value. Teoh, Welch, and Wazzan (1999) provide empirical evidence that the South African boycott to end apartheid, the most prominent divestment campaign to date, did not have any effect on the valuation of companies with ties to South Africa or on the South African financial markets. Two other papers have examined the type of stocks that may be unacceptable to socially responsible investors, who refuse to hold stocks in firms that they see as generating social harm. Hong and Kacperczyk (2009) argue that these stocks, called "sin stocks," have lower price-to-book ratios, less institutional ownership, and less analyst coverage. Geczy, Stambaugh, and Levin (2005) provide similar evidence. Bolton and Kacperczyk (2020) show that that institutional investors implement exclusionary screening based on direct emission intensity (called scope 1 emissions) in a few salient industries.[28] The authors show that, although in aggregate, institutional investors hold a

[27] Institutional ownership more than doubled since 1999. Mean institutional ownership for the US companies in our sample for 1999 is 16.27% and 38.28% in 2018.

[28] The Greenhouse Gas Protocol groups carbon emissions into three categories: direct emissions (scope 1), indirect emissions from consumption of emission intensive inputs (scope 2), and other indirect emissions (scope 3).

significantly smaller fraction of companies with high emission intensity, they do not underweight companies with high levels of emissions. We add to this literature by examining whether institutional ownership influences the relation between firm value and stranded asset risk.

We also examine the effect of analyst coverage and stock liquidity on our results. Studies have shown that analyst coverage and stock market liquidity improve firm value. Jiraporn, Chintrakarn and Kim (2012) show that analysts, as information intermediaries, provide oversight over management and thus help alleviate agency conflicts. Similarly, Fang, Noe and Tice (2009) document that firms with liquid stocks have better performance as measured by the firm market-to-book ratio.

### 4.2. Stranded Assets Risk and Firm Value

In this section, we further examine the effect of stranded assets risk on firm value. First, as an alternative measure of oil reserves, we use *Modified reserves*. This measure was suggested by Delis, Greiff and Ongena (2019) to address a possible problem that might arise because large firms could hold oil reserves in more than one country to (potentially) exploit lax climate policies of countries. An oil firm owing exploration rights for reserves in a country with strict climate policy faces a higher probability of reserves becoming stranded than a firm with fossil fuel reserves in a country with loose climate policy.

To examine this question, for each firm-year, we require data on the amount of total, developed and undeveloped proved oil reserves for each location across different countries. As such data are not readily available in conventional databases, we hand-collect them from the firms' annual reports. To capture the differences in the firms' allocation of oil reserves by country, we calculate the *Modified reserves* of firm $i$ in year $t$ as:

$$Modified\ Reserves_{it} = \sum Reserves_{ij,t} \times Climate\ Policy_{jt} \quad (3)$$

and

$$Modified\ Res\ Growth_{it} = \sum Res\ Growth_{ij,t} \times Climate\ Policy_{jt} \quad (4)$$

where we compute *Modified reserves* measure separately for total reserves and for developed and undeveloped proved oil reserves. In equation (3), *Reserves* is the amount in barrels per dollar of book value of the assets of (total or developed and undeveloped) oil reserves of firm $i$ in country *j* in year *t*. In equation (4), *Res Growth* is the percentage change in (total or developed and undeveloped) oil reserves of firm *i* in country *j* in year *t*. *Climate policy* is the climate policy index of country *j* in year *t*. A detailed measure of a country's climate policy stringency should include both its climate policy goals and its actual climate policy effort. The former is measured by the efficiency in climate policy implementation while the latter is measured by climate policy outcomes such as CO2 emissions.

We are aware of only two datasets that offer information both on emissions and on policy efforts for a large number of countries: (i) the Climate Change Performance Index (CCPI) created by the non-governmental organization and think-tank Germanwatch and (ii) the Climate Change Cooperation Index (C3I) by Bernauer and Böhmelt (2013). The CCPI is an index that evaluates and compares the climate protection performance of 56 countries for the period 2007-2018. A country's performance is assessed based on 14 indicators in the following four categories: (1) GHG Emissions (weighting 40%); (2) Renewable Energy (weighting 20%); (3) Energy Use (weighting 20%); (4) Climate Policy (weighting 20%).

The C3I, on the other hand, evaluates countries' overall climate policy performance, as well as performance in terms of political behavior (output) and emissions (outcome). Currently, the index is available for 172 countries for the period 1996-2014. Both indices take values between 0 and 100 (inclusive) with higher values indicating stricter climate policy (more climate-friendly countries) and as shown by Bernauer and Böhmelt (2013) the two climate policy indices are very highly correlated. We generate a firm-year measure of climate policy exposure (risk) from the product of their reserves (reserves growth) and the C3I from 1999 to 2014 and the CCPI climate policy measure from 2015 to 2018[29]. Based on the above discussion, a higher Modified Reserves measure indicates a higher average level of oil reserves in countries with stricter climate policy.

While the risk of stranded fossil fuel reserves was initially considered to be mostly a long-term risk (Caldecott, Tilbury, and Carey 2014), the 2015 Paris climate agreement was a departure that brought policy action much more forward in time. The transition to a low-carbon economy has now become a medium (and even a short) term concern for financial markets. The second part of our stranded asset risk analysis examines whether the negative relationship between undeveloped reserves growth has become stronger after 2015. We expect

[29] We calculate two different types of the modified reserves measures using separately the C3I and the CCPI data. The results are the same as when we combine the two datasets.

that there has been a change in the sensitivity of firm value to oil reserves growth after the Paris agreement where now financial markets penalize even more the growth of undeveloped oil reserves.

## 5. Estimation Results

### 5.1. Firm Value and Oil Reserves

In this subsection, we discuss the benchmark results to our study. To examine whether market valuations of oil producers reflect the risk of stranded asset, we first examine the relationship between their value and the proved oil reserves they own. Table 3 shows the estimation results from regression specification (1). Columns (1) and (4) show the effect of reserves (total reserves for column (1) and developed and undeveloped reserves for column (4)) on firm value. Columns (2) and (5) show the relation between value and reserves growth whereas columns (3) and (6) combine the two measures of reserves (levels and growth) for total and developed and undeveloped reserves, respectively. From column (1), total reserves are an important component of oil producers' value as the coefficient is positive as well as economically large and statistically significant. From column (2), however, we see that the positive effect of the amount of total reserves is decreasing as the coefficient of total reserves' growth is significantly negative. The magnitude and sign of the coefficients of both oil reserves measures remain the same when we estimate them together (column 3).

When we split total reserves into developed and undeveloped (columns (4) to (6)), we see that the positive effect of total reserves on value (columns (1) and (3)) is due to the amount of developed reserves, which have a significant positive effect. The negative effect of total reserves growth on firm value (columns (2) and (3)), on the other hand, is due to the growth of undeveloped reserves as it has a significant negative effect on firm value. From column (6) we see that the effect of the level of undeveloped reserves is negative and significant. More importantly, the coefficient of undeveloped reserves growth is not only significant but also economically very large with one standard deviation increase in the growth in undeveloped reserves decreasing firm value (Tobin's Q) by 2.6% of the mean firm value. This result is consistent with the recent exploration cuts and undeveloped oil reserves write offs of major North American oil producers.

While the coefficient of the level of undeveloped reserves remains negative, it is not always significant. The significant negative coefficient of undeveloped reserves growth, however, remains robust across all our specifications. This is the key result of our study: the growth in undeveloped reserve has a negative effect on firm value. Our finding supports the 2019 Carbon Tracker report that highlights the fact that future oil reserves that are generated from current capital expenditures will most likely remain in the ground. Our result suggest that market participants recognize, at least partially, that these investments are potentially negative NPV projects that will destroy firm value.

The sign and magnitude of the control variables is largely as expected. Firm size has a significant negative effect on value as typically large firms face fewer growth opportunities. Leverage also has an economically large and significant negative effect. This result is consistent with the findings in Gilje, Loutskina and Murphy (2019) who show that, for their sample of 69 oil and gas firms, the highly levered firms pull forward investment and complete projects early at the expense of long-run project returns and project value. They show that this behavior is particularly pronounced prior to debt renegotiations consistent with equity holders sacrificing long-run project returns to enhance collateral values and, by extension, mitigate lending frictions at debt renegotiations.

Like previous studies, capital expenditures have (mostly) significantly positive effect on oil firm's value; profitability has a significant negative effect whereas dividends are not a significant determinant of oil producers' value. Higher oil prices, on the other hand, result in higher firm valuations as expected.[30]

Next, we examine the effect of extraction costs on our results. We argue that for producers with high extraction costs, the stranded asset risk will be higher as firms will develop first the reserves with the lowest extraction costs. We measure extraction costs as the average annual operating costs divided by annual oil production. Table 4 shows the estimation results from regression specification (2) which extends specification (1) by including the interactions of our reserves measures with the operating costs per barrel of oil for firm $i$ in year $t$. The control variables are the same as in regression specification (1). Columns (1) to (3) show that extraction costs have only a marginal effect on the relationship between total reserves/reserves growth and firm value. Columns (4) to (6), however, show that it is the high extraction costs producers that generate the negative effect of undeveloped reserves and undeveloped reserves growth on firm value. From column (4) and (6), we can see that the

[30] The magnitude and the interpretation of the coefficient of oil price is complicated due to its interaction with the other year-fixed effects.

negative effect of undeveloped reserves on firm value is driven by the high extraction costs oil producers. Similarly, while the undeveloped reserves growth has a significant negative effect for all firms, this effect is stronger (more negative) for the high extraction costs producers. The control variables remain the same as in Table 3.

### 5.2. Stranded Asset Risk and Firm Value

This subsection reports the results from our analysis of the effect of stranded assets risk on firm value. Table 5 shows the estimation coefficients from regression specification (1) using the modified reserves measure in specification (3) and the modified reserves growth in specification (4). The modified measure of reserves accounts for the location diversification of reserves across countries. An oil firm owing exploration rights for reserves in a country with strict climate policy faces a higher probability of reserves becoming stranded than a firm with oil reserves in a country with loose climate policy.

The results in Table 5 remain the same as our main findings in Table 3. The table shows that the growth in modified undeveloped reserves have a significant negative effect on firm value. Our evidence supports the conjecture that for countries with stricter climate policies, the effect of undeveloped reserves growth on value, is larger than for countries with lax climate policy. The coefficient of the growth in modified undeveloped reserves in Table 5 is larger than the same coefficient in Table 3 and the adjusted R-squared is around 50% higher than in all the other regressions. In Table 3 (column 6), one standard deviation increase in undeveloped reserves growth decreases firm value (Tobin's Q) by 2.6%. In Table 5 (column 6), one standard deviation increase in the modified undeveloped reserves growth decreases firm value (Tobin's Q) by more than 10%.

We show further that our results are consistent with markets penalizing firms' investment in undeveloped reserves growth due to climate policy risk. We examine the effect of the 2015 Paris agreement on the sensitivity of firm value to the amount and growth in oil reserves. Table 6 presents the estimation results from regression specification (1) when we include the interaction of the level and growth in our measures of reserves with a dummy variable for the period after the Paris agreement (a dummy variable equal to one for the period 2015-2018) to examine if there has been a change in the sensitivity of firm value to oil reserves. Our empirical results provide support for a much stronger negative effect after 2015. While the growth of undeveloped reserves was valued negatively even before the Paris agreement, after

2015 the (negative) sensitivity of firm value to undeveloped reserves growth almost doubled (column (5) and (6)) from around -0.0008 to around -0.0016. Overall, our evidence is consistent with capital markets penalizing future investment in undeveloped reserves growth due to climate policy risk. The sign and magnitude of the control variables remain the same as in Table 3.

### 5.3 Institutional ownership, Liquidity and Analysts Coverage

In this section, we carry out several robustness tests to our main results. First, in Table 7 we present the estimation coefficients from our benchmark specification for a sub-sample of US firms only. The results remain qualitatively the same (i.e. the same sign and magnitudes although significance levels are lower due to the smaller sample size) as the results for the full sample in Table 3. In particular, the growth in undeveloped reserves have a negative effect on firm value.

In addition, we collect supplementary data on institutional ownership, analysts' coverage and stock liquidity. We examine the effect of these variables on the validity and strength of our results. Table 8 presents the estimation results for specification (1) for subsample of firms with high vs low institutional ownership, analyst coverage and stock liquidity. Table A2 in the Appendix to this paper augments the results from Table 7 by adding institutional ownership, analyst's coverage, and stock market liquidity as control variables. As discussed in section 4, institutional investors can alter the information and trading environment of a firm and therefore affect its value. Most empirical studies on institutional ownership find that, given their independence, expertise, and ability to monitor managers effectively, institutional investors have a positive effect on firm value that is attributable to better monitoring and changes in the corporate governance structures (Aggarwal et al., 2011; Gompers and Metrick, 2001; McConnell and Servaes, 1990; Smith, 1996). Using international samples, Ferreira and Matos (2008) and Bena et al. (2017) document a positive effect of institutional ownership on firm value, with this effect driven primarily by foreign and thus more independent institutions. Homanen and Liang (2018) show that higher institutional ownership is unconditionally correlated with higher firm valuation.

We obtain quarterly data on institutional ownership (as a percentage of shares outstanding) from the Thomson 13F database. We use the yearly average as our measure of institutional ownership. Panel A of Table 8 presents the estimation results from regression specification (1) when we split firms into two subsamples based on their institutional ownership. We use the annual median value of our measure of institutional ownership as the cutoff point between high level (above the median) and low level (below the median) of institutional ownership. For brevity, we only report the coefficients on the reserve's measures. The rest of the coefficients are the same as the results in Table 3[31].

The results in Panel A of Table 8 shows that it is not institutional investors who drive the market penalty for high reserves growth. We find that there is no significant difference in the coefficient of undeveloped reserves growth for firms with high vs low institutional ownership, i.e. high percentage of institutional ownership does not mitigate the negative effect of undeveloped reserves on firm value. Our result that institutional investors are not driving this negative effect is in line with Bolton and Kacperczyk (2020) who find that divestment effects from large institutional investors do not generally explain the documented carbon risk premium.

Panel B of Table 8 presents the results for analyst coverage and its effect on the relation between firm value and oil reserves. We obtain analyst information from the I/B/E/S database. For each fiscal year of a firm, we take the average of the 12 monthly numbers of earnings forecasts given by the summary file and treat that as a raw measure of analyst coverage (Coverage). This measure relies on the fact that most analysts following a firm issue at least one earnings forecast for that firm during the year before its fiscal year ending date and that most of them issue at most one earnings forecast. We then take natural logarithm of (one plus) this raw measure and construct a measure of analyst coverage (LnCoverage). We find that analyst coverage has a strong independent effect on firm value (see Table A2) as it has a significant positive coefficient in all specifications. More importantly, we document some evidence that for firms with higher analyst coverage, the negative market penalty for stranded asset risk is higher. From (1), we see that there a higher penalty on reserves growth for oil producers with high analyst coverage. Similarly, from (2), we see that the negative effect of undeveloped reserves on value is about five times stronger (more negative) for high analyst coverage firms. Previous studies have suggested several channels through which stock analysts can have an effect of firm value. They can improve stock price efficiency, which enhances the feedback in the stock market, increase information acquisition, which improves the information set for managerial decision making and enhance corporate governance, which mitigates the

[31] The full results are available on request.

moral hazard problem (see Brogaard, Shi, Wei and You, 2019). Most importantly, the last row of column (2) shows that analyst coverage does not change the negative relation between firm value and the growth in undeveloped reserves. The coefficients for the two samples are not significantly different.

Finally, in Panel C of Table 8, we also examine the effect of stock market liquidity on firm value and whether the effect of undeveloped reserves differs for stocks with different degree of liquidity. Our measure is the annual turnover, calculated as the annual volume traded (in number of shares) divided by the number of common shares outstanding. The results in Panel C of Table 8 show that stock liquidity also does not change the negative relation between firm value and the growth in undeveloped reserves.

Table A2, in the Appendix, reports the results when we include institutional ownership, analyst coverage and liquidity as control variables in regression specification (3). Most importantly, our result that markets penalize the growth of undeveloped reserves remains robust. We also carry out additional robustness tests (not reported here but available on request) using different definitions of firm value, the oil reserve measures and different control variables. The negative effect of undeveloped reserves on firm value remain the same in magnitude and significance. We estimate specification (1) using alternative measures of firm value: the annual market-to-book ratio of equity (MTB) and the market capitalization in line with studies in the accounting literature. Our results remain unchanged. Similarly, we estimate specification (1) using an alternative measure of the dollar amount of total as well developed and undeveloped proved reserves calculated by multiplying the number of barrels by the average oil price per barrel sold and then scale them by total assets. The results remain the same. Overall, we provide robust evidence that markets penalize future investment in undeveloped reserves growth due to climate policy risk.

## Conclusions

In this paper, we provide evidence on the relation between oil companies' firm value and the growth in their developed and undeveloped oil reserves. Previous studies have failed to document a significant negative stock market reaction to stranded asset risk. Our results suggest that while oil reserves are an important component of firm value, the effect of growth in these reserves, on the other hand, has a significantly negative effect on value throughout the sample period. This negative effect is particularly stronger after the 2015 Paris agreement.

When we decompose total reserves into developed and undeveloped, we show that the positive effect is due to the amount of developed oil reserves and the negative effect is due to the growth of undeveloped oil reserves. One standard deviation increase in the growth of undeveloped proved oil reserves decreases firm value (Tobin's *Q*) by 2.6%.

Our evidence is consistent with markets penalizing firms' undeveloped reserves growth due to climate policy risk. First, we document that oil producers with higher extraction costs face higher risk of stranded assets as firms develop first the reserves with the lowest extraction costs. Our results show that the positive effect of total reserves on firm value is much smaller for oil producers with high extraction costs. On the other hand, the negative effect of undeveloped reserves growth on firm is generated by the high extraction costs oil producers.

Second, our estimation results based on the modified reserves measure also suggest that capital markets consider the possibility of future stranded assets. An oil producer owing exploration rights for oil reserves in a country with strict climate policy faces a higher probability of reserves becoming stranded than a firm with oil reserves in a country with loose climate policy. We show that the growth in modified undeveloped reserves have a stronger negative effect on firm value.

Finally, our results show that while analyst coverage has an independent effect on oil producers' value, it does not explain or change the negative effect of undeveloped oil reserves growth on firm value. The results are similar when we consider institutional ownership and stock market liquidity. Overall, our results suggest that the firm's trading environment or informational opacity do not explain the relation between the growth of undeveloped oil reserves and the decrease in firm value.

Our paper contributes to research that documents evidence for the climate change risk of fossil fuel firms. To the best of our knowledge, we are the first study to show that investing in developing future oil reserves is a not a positive NPV proposition that could potentially destroy firm value. We hope that our findings help to spur both theoretical and empirical research in this area. For example, future research can examine whether a transition to a renewable energy and greener production in general is recognized by capital markets and therefore increases firm value.

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Figure 1: Sample Firms Distribution and Oil Prices

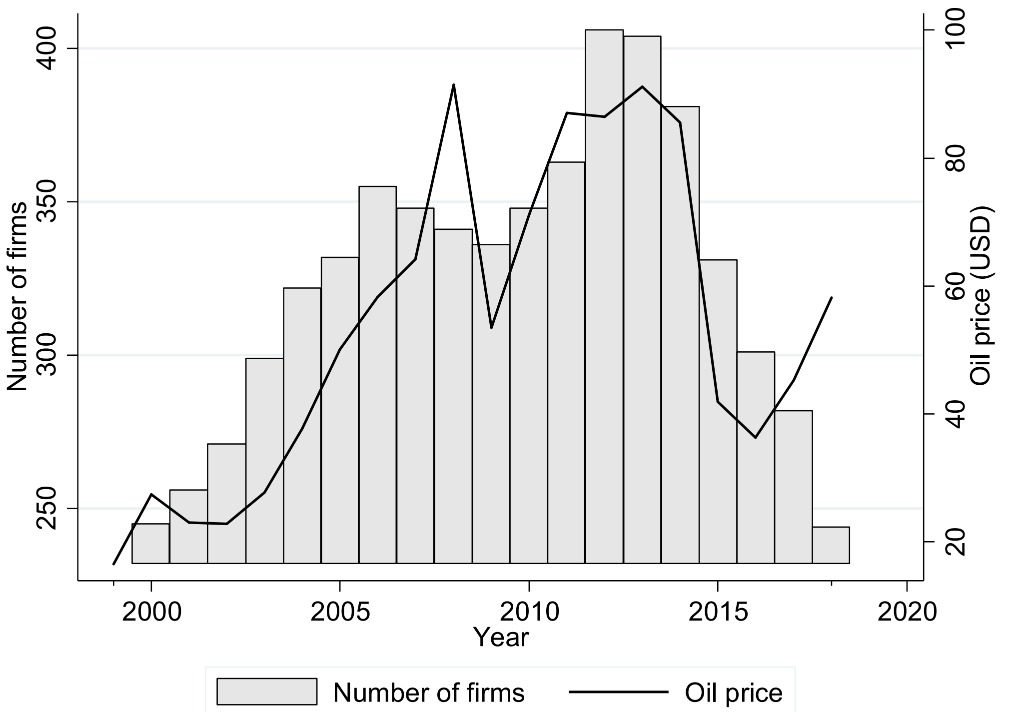

Table 1: COMPUSTAT Oil&Gas Firms Distribution by Country

The table presents summary statistics for oil producers from the COMPUSTAT Industry Segment database for the period 1999 to 2018. In columns (2) to (6), book assets, Tobin's Q, market leverage, capital expenditures and total proved oil reserves are the average values for all firm-year observations in a given country. Column (7) reports the sum of total proved reserves for all firms in a given country. Variable definitions are in Appendix A1.

| Country | Number of Firms | Book Assets (million US$) | Tobin's Q | Leverage | CAPEX | Firm Reserves (thousand barrels) | Country Reserves (thousand barrels) |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Argentina | 3 | 11,781 | 0.7823 | 37.23% | 11.93% | 290,115 | 870,346 |
| Australia | 5 | 26,142 | 5.3352 | 33.40% | 23.63% | 111,009 | 555,043 |
| Bermuda | 5 | 2,160 | 1.4415 | 41.17% | 23.15% | 68,281 | 341,405 |
| Brazil | 1 | 222,068 | 0.9891 | 40.01% | 14.42% | 8,261,500 | 8,261,500 |
| Canada | 398 | 1,562 | 1.3212 | 22.87% | 36.52% | 65,225 | 28,046,557 |
| China | 2 | 292,576 | 0.9258 | 26.24% | 13.84% | 4,653,400 | 9,306,800 |
| Columbia | 1 | 38,380 | 1.4883 | 20.57% | 12.75% | 1,127,000 | 1,127,000 |
| Cayman Islands | 8 | 363 | 1.3088 | 44.28% | 20.87% | 22,812 | 182,495 |
| Spain | 1 | 68,429 | 0.8103 | 40.24% | 8.09% | 584,000 | 584,000 |
| France | 1 | 256,762 | 1.0381 | 21.11% | 10.01% | 6,049,000 | 6,049,000 |
| Great Britain | 7 | 125,243 | 1.3278 | 11.94% | 17.97% | 2,602,505 | 18,217,536 |
| Hong Kong | 1 | 98,691 | 1.5736 | 12.69% | 17.11% | 3,556,400 | 3,556,400 |
| Italy | 1 | 135,525 | 0.8665 | 24.92% | 8.78% | 3,540,000 | 3,540,000 |
| Jersey | 2 | 384 | 2.9259 | 10.09% | 70.71% | 28,654 | 57,308 |
| Netherlands | 1 | 115,687 | 1.4967 | 6.75% | 7.84% | 2,844,600 | 2,844,600 |
| Norway | 2 | 75,039 | 0.8293 | 23.60% | 10.73% | 1,653,000 | 3,306,000 |
| Russia | 3 | 108,932 | 0.5085 | 38.26% | 9.58% | 9,165,000 | 27,495,000 |
| USA | 281 | 4,450 | 2.1143 | 30.31% | 29.09% | 139,166 | 45,785,524 |
| South Africa | 1 | 32,032 | 1.1196 | 17.38% | 14.66% | 1,228,200 | 1,228,200 |

Table 2: Summary statistics

The table contains summary statistics for 600 North American oil producers for the period 1999 to 2018. Panel A reports statistics for firm-level financial variables, and oil reserves. Panel B compares the financial characteristics of firms with low (bottom quartile) vs high (top quartile) total proved oil reserves and their growth. Variable definitions are in Appendix A1. Diff is the $p$ value from a $t$-test for differences in means. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| Panel A: Summary Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Mean | Std dev | Median | 5% | 95% | |
| Assets (million USD) | $5,573 | $24,258 | $352 | $9 | $23,618 | |
| Tobin's Q | 2.63 | 59.16 | 1.08 | 0.42 | 3.29 | |
| Market leverage | 26.64% | 0.25 | 20.51% | 0.00 | 80.15% | |
| Capital expenditures | 36.21% | 1.21 | 21.20% | 2.18% | 95.06% | |
| Profitability | 6.57% | 2.18 | 13.89% | -34.19% | 45.11% | |
| Dividends | 2.26% | 0.28 | 0 | 0 | 10.36% | |
| Oil Reserves (barrels per US$ of total assets) | | | | | | |
| Total reserves | 0.0435 | 0.0923 | 0.0233 | 0.0008 | 0.1379 | |
| Developed reserves | 0.0244 | 0.0614 | 0.0136 | 0.0005 | 0.0754 | |
| Panel B: Total Reserves, Growth and Financials | | | | | | |
| | Low Reserves | High Reserves | Diff | Low Growth | High Growth | Diff |
| Assets (million $US) | 1,495 | 5,913 | 0.00*** | 3,170 | 2,130 | 0.06* |
| | (4,970 ) | (22,551) | | (14,443) | (11,306) | |
| Tobin's Q | 1.44712 | 1.7160 | 0.05** | 1.5286 | 1.3260 | 0.00*** |
| | (2.9038) | (1.2211) | | (2.8544) | (1.0597) | |
| Leverage | 24.46% | 25.48% | 0.3324 | 22.95% | 32.80% | 0.00*** |
| | (0.253) | (0.241) | | (0.2305) | (0.2899) | |
| Capital expenditures | 39.93% | 35.51% | 0.5399 | 22.41% | 43.09% | 0.00** |
| | (1.675) | (1.573) | | (0.2268) | (0.3759) | |

Table 3: Oil Reserves and Firm Value

The table presents estimates from regression specification (1) for the period from 1999 to 2018. The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. All specifications include firm-year fixed effects. The $p$-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total reserves | 0.0260** | | 0.0263* | | | |
| | (0.024) | | (0.073) | | | |
| Growth total reserves | | -0.0000420** | -0.0000411** | | | |
| | | (0.021) | (0.024) | | | |
| Developed reserves | | | | 0.835* | | 1.595*** |
| | | | | (0.065) | | (0.004) |
| Undeveloped reserves | | | | -0.112 | | -0.234** |
| | | | | (0.136) | | (0.011) |
| Growth developed reserves | | | | | 0.00346 | 0.00502** |
| | | | | | (0.136) | (0.039) |
| Growth undeveloped reserves | | | | | -0.000850*** | -0.000928*** |
| | | | | | (0.001) | (0.000) |
| Size | -0.115*** | -0.0706*** | -0.0698*** | -0.111** | -0.0686*** | -0.0580** |
| | (0.007) | (0.001) | (0.001) | (0.016) | (0.005) | (0.017) |
| Leverage | -0.613*** | -0.701*** | -0.700*** | -0.591*** | -0.733*** | -0.727*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Capital expenditures | 0.0356 | 0.0631** | 0.0618** | 0.0536 | 0.0994** | 0.0964** |
| | (0.253) | (0.026) | (0.030) | (0.113) | (0.014) | (0.021) |
| Profitability | -0.0352*** | -0.132* | -0.126* | -0.0353*** | -0.173** | -0.177** |
| | (0.000) | (0.074) | (0.098) | (0.000) | (0.012) | (0.011) |
| Dividends | -0.00376 | 0.0611 | 0.0707 | -0.116 | 0.357 | 0.240 |
| | (0.988) | (0.839) | (0.814) | (0.654) | (0.375) | (0.568) |
| Oil price | 0.773*** | 0.758*** | 0.760*** | 0.788*** | 0.833*** | 0.843*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 3,701 | 3,669 | 3,669 | 3,510 | 2,969 | 2,969 |
| Adjusted R-squared | 0.264 | 0.272 | 0.272 | 0.265 | 0.306 | 0.311 |

Table 4: Oil Reserves, Operating Costs and Firm Value

The table presents estimates from regression specification (2) for the period from 1999 to 2018. The dependent variable is log Tobin's Q. Cost is average annual operating costs divided by the annual oil production. Variable definitions are in Table A1 in the Appendix. All specifications include firm-year fixed effects. The *p*-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total reserves | 0.0437*** | | 0.0432*** | | | |
| | (0.000) | | (0.006) | | | |
| Total reserves*Cost | -0.0608* | | -0.0592* | | | |
| | (0.084) | | (0.098) | | | |
| Growth total reserves | | -0.0000625** | -0.0000275 | | | |
| | | (0.047) | (0.385) | | | |
| Growth total reserves*Cost | | 0.000000970 | -0.00000131 | | | |
| | | (0.542) | (0.414) | | | |
| Developed reserves | | | | 0.685 | | 1.282** |
| | | | | (0.206) | | (0.017) |
| Developed reserves*Cost | | | | -0.0184*** | | 0.203 |
| | | | | (0.009) | | (0.266) |
| Undeveloped reserves | | | | -0.0493 | | -0.154* |
| | | | | (0.577) | | (0.073) |
| Undeveloped reserves*Cost | | | | -0.145*** | | -0.159*** |
| | | | | (0.000) | | (0.000) |
| Growth developed reserves | | | | | 0.00221 | 0.00834 |
| | | | | | (0.728) | (0.141) |
| Growth developed reserves*Cost | | | | | 0.000709 | -0.000831 |
| | | | | | (0.623) | (0.426) |
| Growth undeveloped reserves | | | | | -0.00119*** | -0.00146*** |
| | | | | | (0.001) | (0.000) |
| Growth undeveloped reserves*Cost | | | | | -0.000570*** | -0.000529*** |
| | | | | | (0.005) | (0.003) |
| Size | -0.115** | -0.0643*** | -0.0652*** | -0.116** | -0.0658** | -0.0582** |
| | (0.020) | (0.008) | (0.007) | (0.029) | (0.012) | (0.029) |
| Leverage | -0.537*** | -0.633*** | -0.632*** | -0.501*** | -0.688*** | -0.677*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Capital Expenditures | 0.0474 | 0.0770** | 0.0738** | 0.0550 | 0.0995** | 0.0904* |
| | (0.223) | (0.040) | (0.048) | (0.204) | (0.037) | (0.063) |
| Profitability | -0.0340*** | -0.149* | -0.139 | -0.0339*** | -0.216*** | -0.218*** |
| | (0.000) | (0.070) | (0.100) | (0.000) | (0.003) | (0.004) |
| Dividends | 0.00506 | 0.0906 | 0.108 | -0.0992 | 0.489 | 0.403 |
| | (0.987) | (0.814) | (0.780) | (0.745) | (0.335) | (0.443) |
| Oil price | 0.751*** | 0.778*** | 0.780*** | 0.763*** | 0.871*** | 0.878*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 2,859 | 2,834 | 2834 | 2,738 | 2,325 | 2,325 |
| Adjusted R-squared | 0.253 | 0.255 | 0.259 | 0.253 | 0.293 | 0.303 |

Table 5: Firm Value, Oil Reserves Location and Climate Policy

The table presents estimates from regression specification (1) using the modified reserves measures. The estimation period is from 1999 to 2018. The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. All specifications include firm-year fixed effects. The *p*-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total modified reserves | 0.0910 | | 0.147 | | | |
| | (0.746) | | (0.600) | | | |
| Growth total modified reserves | | -0.000368*** | -0.000360** | | | |
| | | (0.006) | (0.019) | | | |
| Developed modified reserves | | | | 0.055 | | 0.056* |
| | | | | (0.144) | | (0.057) |
| Undeveloped modified reserves | | | | 0.448 | | 0.759 |
| | | | | (0.307) | | (0.518) |
| Growth developed modified reserves | | | | | 0.00138 | 0.00272 |
| | | | | | (0.654) | (0.358) |
| Growth undeveloped modified reserves | | | | | -0.000245*** | -0.000453*** |
| | | | | | (0.007) | (0.001) |
| Size | -0.176*** | -0.162*** | -0.161*** | -0.161*** | -0.0987** | -0.0826** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.015) | (0.036) |
| Leverage | -0.678*** | -0.716*** | -0.720*** | -0.670*** | -0.712*** | -0.719*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Capital Expenditures | -0.0338 | -0.0196 | -0.0198 | -0.0189 | 0.0476 | 0.0476 |
| | (0.276) | (0.603) | (0.601) | (0.609) | (0.572) | (0.568) |
| Profit | -0.00542** | -0.0298 | -0.0350 | -0.00616*** | 0.0519 | 0.0333 |
| | (0.019) | (0.789) | (0.753) | (0.003) | (0.732) | (0.802) |
| Dividends | 0.137 | 0.180 | 0.174 | -0.0388 | 0.336 | 0.200 |
| | (0.605) | (0.594) | (0.606) | (0.882) | (0.382) | (0.595) |
| Oil price | 0.366** | 0.414** | 0.413** | 0.384** | 0.482*** | 0.488*** |
| | (0.016) | (0.011) | (0.011) | (0.013) | (0.000) | (0.000) |
| Observations | 1,831 | 1,722 | 1,722 | 1,665 | 1,256 | 1,256 |
| Adjusted R-squared | 0.417 | 0.426 | 0.426 | 0.425 | 0.450 | 0.459 |

Table 6: Firm Value, Oil Reserves and the 2015 Paris Agreement

The table presents estimates from regression specification (1). The estimation period is from 1999 to 2018 and the oil reserves measures are interacted with a dummy variable Paris equal to one for the period 2015-2018. The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. All specifications include firm-year fixed effects. The *p*-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total reserves | -1.193 | | -0.820 | | | |
| | (0.476) | | (0.599) | | | |
| Total reserves*Paris | 1.220 | | 0.847 | | | |
| | (0.466) | | (0.586) | | | |
| Growth total reserves | | -0.0000541*** | -0.0000580** | | | |
| | | (0.005) | (0.011) | | | |
| Growth total reserves*Paris | | 0.000172 | 0.000178 | | | |
| | | (0.154) | (0.140) | | | |
| Developed reserves | | | | 0.828* | | 1.577*** |
| | | | | (0.066) | | (0.004) |
| Undeveloped reserves | | | | -0.110 | | -0.231** |
| | | | | (0.141) | | (0.010) |
| Undeveloped reserves*Paris | | | | -1.440 | | -2.006 |
| | | | | (0.553) | | (0.376) |
| Growth developed reserves | | | | | 0.00341 | 0.00503** |
| | | | | | (0.142) | (0.038) |
| Growth undeveloped reserves | | | | | -0.000771*** | -0.000866*** |
| | | | | | (0.003) | (0.001) |
| Growth undeveloped reserves*Paris | | | | | -0.000700* | -0.000794** |
| | | | | | (0.061) | (0.043) |
| Size | -0.115*** | -0.0707*** | -0.0704*** | -0.111** | -0.0685*** | -0.0591** |
| | (0.007) | (0.001) | (0.001) | (0.016) | (0.005) | (0.015) |
| Leverage | -0.614*** | -0.702*** | -0.701*** | -0.590*** | -0.732*** | -0.726*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Capital expenditures | 0.0348 | 0.0627** | 0.0614** | 0.0533 | 0.0998** | 0.0989** |
| | (0.264) | (0.027) | (0.031) | (0.114) | (0.014) | (0.019) |
| Profitability | -0.0349*** | -0.132* | -0.131* | -0.0353*** | -0.173** | -0.200** |
| | (0.000) | (0.075) | (0.097) | (0.000) | (0.012) | (0.012) |
| Dividends | 0.00467 | 0.0625 | 0.0732 | -0.115 | 0.359 | 0.259 |
| | (0.986) | (0.835) | (0.811) | (0.658) | (0.373) | (0.535) |
| Oil price | 0.764*** | 0.756*** | 0.750*** | 0.787*** | 0.829*** | 0.832*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 3,701 | 3,669 | 3,669 | 3,510 | 2,969 | 2,969 |
| Adjusted R-squared | 0.265 | 0.272 | 0.272 | 0.265 | 0.306 | 0.313 |

Table 7: Firm Value and Oil Reserves: US Oil Producers

The table presents estimates from regression specification (1) for US oil producers for the period from 1999 to 2018. The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. All specifications include firm-year fixed effects. The *p*-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total reserves | 0.0297** | | 0.0322* | | | |
| | (0.014) | | (0.059) | | | |
| Growth total reserves | | -0.0000266 | -0.0000253 | | | |
| | | (0.152) | (0.176) | | | |
| Developed reserves | | | | 0.500 | | 0.989* |
| | | | | (0.358) | | (0.072) |
| Undeveloped reserves | | | | -0.0512 | | -0.131 |
| | | | | (0.559) | | (0.146) |
| Growth developed reserves | | | | | 0.00359 | 0.00528 |
| | | | | | (0.352) | (0.181) |
| Growth undeveloped reserves | | | | | -0.000639* | -0.000764** |
| | | | | | (0.070) | (0.030) |
| Size | -0.125** | -0.0557** | -0.0542** | -0.123* | -0.0702*** | -0.0629** |
| | (0.048) | (0.033) | (0.038) | (0.061) | (0.007) | (0.018) |
| Leverage | -0.448*** | -0.591*** | -0.589*** | -0.442*** | -0.663*** | -0.655*** |
| | (0.005) | (0.000) | (0.000) | (0.006) | (0.000) | (0.000) |
| Capital Expenditures | 0.0313 | 0.0523 | 0.0496 | 0.0274 | 0.0662 | 0.0612 |
| | (0.400) | (0.153) | (0.171) | (0.523) | (0.116) | (0.153) |
| Profitability | -0.0319*** | -0.143 | -0.132 | -0.0321*** | -0.187** | -0.181** |
| | (0.000) | (0.132) | (0.181) | (0.000) | (0.020) | (0.027) |
| Dividends | -0.128 | -0.0246 | -0.00117 | -0.179 | 0.0954 | 0.0296 |
| | (0.687) | (0.948) | (0.998) | (0.576) | (0.889) | (0.968) |
| Oil price | 0.910*** | 0.916*** | 0.920*** | 0.924*** | 1.006*** | 1.014*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 2,136 | 2,112 | 2,112 | 2,102 | 1,816 | 1,816 |
| Adjusted R-squared | 0.206 | 0.207 | 0.207 | 0.206 | 0.277 | 0.279 |

Table 8: Institutional Ownership, Analysts Coverage and Liquidity

The table presents estimates from regression specification (1) for a sample of US oil producers from 1999 to 2018. The regressions are estimated separately for high level (above median) and low level (below median) firms. Difference represents t-test for differences in coefficients. Panel A splits sample firms by their institutional ownership (% of shares held by institutional investors); Panel B by analysts coverage (number of analysts forecasts ); and Panel C by stock market liquidity (annual volume traded divided by shares outstanding). The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. For brevity, we do not report the coefficients of the control variables. All specifications include firm-year fixed effects. The p-statistics (in parenthesis) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | | | (2) | | |
|---|---|---|---|---|---|---|
| | High | Low | Difference | High | Low | Difference |
| Panel A: Institutional ownership | | | | | | |
| Total reserves | 0.0130 | -0.0915 | 0.386 | | | |
| | (0.367) | (0.711) | | | | |
| Growth total reserves | 0.000430 | -0.0000411 | 0.764 | | | |
| | (0.823) | (0.114) | | | | |
| Developed reserves | | | | 1.388* | 1.271 | 0.648 |
| | | | | (0.095) | (0.274) | |
| Undeveloped reserves | | | | -0.201 | -0.273 | 0.304 |
| | | | | (0.156) | (0.469) | |
| Growth developed reserves | | | | 0.00876 | 0.000832 | 0.519 |
| | | | | (0.136) | (0.919) | |
| Growth undeveloped reserves | | | | -0.00106** | -0.00138** | 0.906 |
| | | | | (0.030) | (0.012) | |
| Observations | 1,474 | 1,336 | | 1,366 | 982 | |
| Adjusted R-squared | 0.341 | 0.277 | | 0.350 | 0.337 | |

Table 8: Institutional Ownership, Analysts Coverage and Liquidity (CONTINUED)

| | (1) | | | (2) | | |
|---|---|---|---|---|---|---|
| | High | Low | Difference | High | Low | Difference |
| Panel B: Analysts coverage | | | | | | |
| Total reserves | -0.124 | 0.0446** | 0.751 | | | |
| | (0.726) | (0.015) | | | | |
| Growth total reserves | -0.000856*** | -0.0000494 | 0.003** | | | |
| | (0.001) | (0.687) | | | | |
| Developed reserves | | | | 0.976 | 2.072*** | 0.588 |
| | | | | (0.338) | (0.000) | |
| Undeveloped reserves | | | | -1.353*** | -0.285*** | 0.031** |
| | | | | (0.001) | (0.001) | |
| Growth developed reserves | | | | -0.00428 | 0.0123* | 0.054* |
| | | | | (0.527) | (0.055) | |
| Growth undeveloped reserves | | | | -0.00118*** | -0.00158*** | 0.838 |
| | | | | (0.001) | (0.004) | |
| Observations | 1,489 | 1,312 | | 1,366 | 991 | |
| Adjusted R-squared | 0.466 | 0.231 | | 0.487 | 0.276 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Panel C: Stock Market Liquidity | | | | | | |
| Total reserves | -0.334 | 0.0357 | 0.985 | | | |
| | (0.526) | (0.123) | | | | |
| Growth total reserves | -0.0000568 | -0.0000949 | 0.670 | | | |
| | (0.411) | (0.834) | | | | |
| Developed reserves | | | | 1.437 | 1.129 | 0.046** |
| | | | | (0.271) | (0.206) | |
| Undeveloped reserves | | | | -0.903 | -0.160 | 0.192 |
| | | | | (0.212) | (0.275) | |
| Growth developed reserves | | | | 0.0289* | 0.00411 | 0.135 |
| | | | | (0.069) | (0.262) | |
| Growth undeveloped reserves | | | | -0.00206* | -0.00779* | 0.128 |
| | | | | (0.098) | (0.062) | |
| Observations | 1,082 | 935 | | 1,011 | 749 | |
| Adjusted R-squared | 0.295 | 0.209 | | 0.373 | 0.288 | |

# Appendix A1: Variable definitions

| Variable | Definition |
|---|---|
| Panel A: Firm characteristics | |
| Tobin's Q | Market value of equity pus liquidation value of preferred equity plus book value of debt divided by assets. |
| Assets (million USD) | Book value of total assets; Size is the log of beginning-of-year assets. |
| CAPEX | Capital expenditures divided by beginning-of-year (lagged) assets. |
| Leverage | Market leverage is defined as total book debt divided by equity market cap plus debt. |
| Capital Expenditures | Capital expenditures divided by beginning-of-year (lagged) assets. |
| Profitability | Profitability is earnings before interest, taxes, depreciation, and amortization scaled by beginning-of-year assets. |
| Dividends | Dividends are dividends paid divided by beginning-of-year assets. |
| Cost | Average annual operating costs divided by annual oil production. |
| Inst. ownership | Percentage of shares outstanding held by institutional investors. |
| Analysts coverage | The average number of analysis forecasts for the year. |
| Stock market liquidity | Annual volume traded divided by number of shares outstanding. |
| Panel B: Industry specific | |
| Total reserves | Total proved reserves/Assets (barrel per $ of total assets) |
| Developed reserves | Developed proved reserves/Assets (barrel per $ of total assets) |
| Undeveloped reserves | (Total reserves - developed reserves)/Assets (barrel per $ of total assets) |
| Modified reserves | Weighted average measure of reserves; weights are countries' climate index |

Appendix A2: Firm Value and Oil Reserves: US Oil Producers

The table presents estimates from regression specification (1) for 281 US firms for the period from 1999 to 2018. The dependent variable is the logarithm of Tobin's Q. Variable definitions are in Table A1 in the Appendix. We include institutional ownership (% of shares held by institutional investors), analysts coverage (number of analysts forecasts) and liquidity (annual volume traded divided by shares outstanding) as additional controls. All specifications include firm-year fixed effects. The *p*-values (in parentheses) are based on clustered standard errors across firms. * indicates significance at the 10% level, ** at the 5% level, and *** at the 1% level.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Total reserves | 0.764 | | 0.837 | | | |
| | (0.179) | | (0.151) | | | |
| Growth total reserves | | -0.0156** | -0.0187*** | | | |
| | | (0.031) | (0.007) | | | |
| Developed reserves | | | | 0.738 | | 0.794 |
| | | | | (0.343) | | (0.322) |
| Undeveloped reserves | | | | 0.787 | | 0.285 |
| | | | | (0.387) | | (0.723) |
| Growth developed reserves | | | | | 0.0113 | 0.0143 |
| | | | | | (0.321) | (0.231) |
| Growth undeveloped reserves | | | | | -0.000399* | -0.000355* |
| | | | | | (0.080) | (0.098) |
| Inst. ownership | 0.00117 | -0.000831 | 0.000682 | 0.00104 | -0.00434 | -0.00331 |
| | (0.875) | (0.896) | (0.924) | (0.893) | (0.418) | (0.542) |
| Analyst coverage | 0.0159*** | 0.0162*** | 0.0158*** | 0.0155*** | 0.0161*** | 0.0158*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Stock liquidity | 0.00220 | 0.00205 | 0.00203 | 0.00197 | 0.00189 | 0.00183 |
| | (0.261) | (0.296) | (0.299) | (0.306) | (0.242) | (0.251) |
| Size | -0.222*** | -0.230*** | -0.221*** | -0.215*** | -0.263*** | -0.254*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Leverage | -0.811*** | -0.810*** | -0.812*** | -0.813*** | -0.813*** | -0.814*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Capital expenditures | -0.128* | -0.122** | -0.141** | -0.131** | -0.189*** | -0.202*** |
| | (0.052) | (0.047) | (0.028) | (0.038) | (0.000) | (0.000) |
| Profitability | -0.177 | -0.169 | -0.181 | -0.184 | -0.163 | -0.169 |
| | (0.198) | (0.223) | (0.185) | (0.178) | (0.333) | (0.312) |
| Dividends | 1.635 | 1.821 | 1.689 | 1.651 | 1.519 | 1.412 |
| | (0.148) | (0.129) | (0.145) | (0.164) | (0.131) | (0.168) |
| Oil price | 0.701*** | 0.672*** | 0.682*** | 0.701*** | 0.658*** | 0.665*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Observations | 1,173 | 1,168 | 1,168 | 1,149 | 1,094 | 1,094 |
| Adjusted R-squared | 0.442 | 0.439 | 0.443 | 0.437 | 0.457 | 0.458 |