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SLAYING GIANTS? DYNAMIC IMPACTS OF SANCTIONS ON OIL COMPANIES

Erik Katovich

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Economists for Ukraine (Econ4UA)

Website: https://econ4ua.org/   Email: info@econ4ua.org

ABSTRACT

Slaying Giants? Dynamic Impacts of Sanctions on Oil Companies

Economic sanctions increasingly target large firms. But complex organizations can adapt dynamically, resulting in delayed or unintended impacts. Leveraging oil field-level panel data and a natural experiment created by Russia's 2014 invasion of Ukraine, I find that sanctions cause short-termism: sanctioned oil companies increase current production while cutting exploration and abandoning undeveloped fields. A dynamic model disentangles mechanisms: technology sanctions raise exploration costs while financial sanctions raise discount rates, jointly inducing firms to prioritize immediate extraction. While sanctions can inflict long-term damage on firms, they may inadvertently boost current revenues and fail to bind within policymakers' time horizons.

JEL CLASSIFICATION: F51, Q34, D22
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Erik Katovich
University of Connecticut
Department of Agricultural and Resource Economics
Mansfield, CT
erik.katovich@uconn.edu

1 Introduction

Use of economic sanctions has increased sharply in recent decades, with nearly 5,000 country-pairs and 27% of global trade impacted in 2023 (Felbermayr et al., 2024). Sanctions frequently target firms: 1,384 companies were listed as sanction targets in 2025, of which 22% were Chinese and 63% were Russian (OpenSanctions, 2025). Targeted organizations may adapt to sanctions along multiple dimensions, including reallocation of resources across time and space, divestment or acquisition of assets, or changes in corporate partnerships – resulting in complex and often unintended consequences. I propose a mechanism underlying these responses: sanction-induced short-termism. By raising the cost of capital and restricting access to frontier technology, sanctions devalue long-term investments relative to current production. This concept applies broadly, from firms drawing down inventories rather than investing in R&D, to governments liquidating sovereign wealth funds, to militaries depleting weapon stockpiles rather than modernizing their forces.[1]

This paper provides the first test of sanction-induced short-termism, using oil companies as a setting where both current extraction and long-term investment are precisely observable across large and heterogeneous asset portfolios. Oil companies are frequent targets for sanctions because they form the backbone of oil-dependent economies and generate essential revenue streams for governments.[2] Empirically, I leverage a natural experiment created by Russia's 2014 invasion of Ukraine, which triggered technology and financial sanctions on several Russian oil companies while leaving other companies relatively unaffected. Using field-level panel data on 8,313 Russian oil and gas fields from Rystad Energy (2025), I estimate event studies that compare outcomes in fields operated by sanctioned versus non-sanctioned firms.

Most studies to date use cross-country comparisons to estimate the impacts of sanctions, and only a few leverage firm-level data (Korovkin and Makarin, 2023; Nigmatulina, 2023; Ahn and Ludema, 2020). In this paper, I exploit much richer variation at the oil field-level,

[1] Chinese technology company Huawei's adaptation to US technology restrictions in 2018 illustrates the boundary conditions of this mechanism: access to domestic innovation capacity and financing enabled the firm to accelerate R&D rather than postpone it (Shrivastava, 2024). Short-termism may be most likely when sanctioned inputs are difficult to substitute.

[2] Oil and gas provide 30-50% of government revenues in Russia, 60% in Venezuela and Iran, and 97% in Libya (Yermakov, 2024; Mathiasen and Martinez, 2019; Farzanegan, 2011; EIA, 2023).

allowing me to analyze multiple dimensions of dynamic adjustment to sanctions within firms. I estimate heterogeneity in sanction impacts by fields' cost structure (measured by breakeven price at time of discovery), segment (i.e., offshore or conventional), and development stage. I also explore changes in asset-level ownership and multinational participation, as well as geospatial effects on night-light intensity and gas flaring around oil fields.

After sanctions targeting technology inputs and financing were imposed by the United States and European Union on several Russian oil companies in 2014, event studies reveal that oil equivalent production in fields operated by these companies *increased* significantly (+2.8%, or 44,000 barrels per field-year, by 2016) relative to fields operated by non-sanctioned companies and remained higher through 2019. However, sanctioned fields also experienced deep and sustained cuts in exploration investment (-12% by 2016 and -15% by 2021, equivalent to US$1.85 million per field), leading to depletion of oil and gas reserves (-35% by 2021) relative to non-sanctioned fields. Capital expenditures (capex), associated with field development, display noisier pre-trends but follow a similar pattern of decline after sanctions. In line with short-term production growth, economic activity around oil fields, measured by night light intensity, also increased significantly following the 2014 sanctions, including localized effects within 5km of fields (+0.6% of GDP in 2016) and smaller spillover effects between 5-15km and 15-25km from fields. Satellite-measured night-lights thus corroborate results from Rystad data, validating data quality.

Heterogeneity analysis reveals that post-2014 production growth in sanctioned Russian fields came from both high and low-cost and onshore and offshore fields. In contrast, exploration and capex cuts were almost entirely concentrated in high-cost and offshore fields. By 2021, exploration investment fell by 28% in high-cost fields, and by a striking 78% in offshore fields, relative to non-sanctioned fields of the same type. Consequently, reserves fell much more in these same high-cost and offshore fields (-60% and -68%, respectively, by 2021). Splitting fields instead by their life-cycle stage in 2013 reveals that increased production came primarily from fields discovered within the previous 10 years – precisely those that required less exploration and development investments but still had reserves available to ramp up production. In contrast, cuts to exploration and capex were focused on undeveloped fields. These findings align with the stated goals and design of sanctions as described contemporaneously in the New York Times in 2014: to "*curtail access to Western technology as [Russia] seeks to tap new Arctic, deep sea, and shale oil reserves... not to inhibit current oil production but to cloud Russia's energy future* (Baker et al., 2014)."

Sanctioned companies also engaged in substantial field-level ownership changes. Fields operated by a sanctioned company in 2013 were 29 percentage points more likely to be abandoned by 2021 – with this effect driven almost entirely by fields that were undeveloped when sanctions were imposed. Divestment effects are largest in offshore fields, though pre-trends for abandonment rates in this sub-group are not parallel. Sanctioned companies did not pass off assets to their subsidiaries, likely because majority-owned subsidiaries of a sanctioned company are also subject to sanctions. Multinational participation in joint ventures fell sharply in sanctioned fields relative to non-sanctioned fields after 2014, with this effect concentrated in offshore fields (-15% by 2021 and -25% by 2024). Participation by companies based in the EU or OECD (a proxy for sanction compliance) remained unchanged after the 2014 sanctions, but declined sharply after Russia's 2022 invasion of Ukraine, while participation by countries based outside the EU or OECD did not display a similar decline after 2022. Finally, I estimate that sanctioned firms were 53% more productive than non-sanctioned firms at converting exploration investment into reserves prior to 2014. Reallocation of exploration capital toward non-sanctioned operators after 2014 thus likely generated aggregate efficiency losses beyond direct damage to sanctioned firms, in line with findings in Nigmatulina (2023).

To quantify long-run consequences of sanction-induced short-termism and disentangle the contributions of technology and financial sanctions, I develop a dynamic model of oil company decision-making across a portfolio of heterogeneous fields. In the baseline, a representative firm maximizes intertemporal profits from each field by making exploration and development investment decisions that unlock producible reserves, followed by reserve depletion under convex production costs. I introduce three distortions reflecting the design of sanctions imposed on oil companies in 2014. First, technology sanctions act as a tax on exploration and development, disproportionately reducing investment in undeveloped fields with high technical requirements. Second, financial sanctions increase the firm's cost of capital, devaluing future returns and bringing production forward in time. Third, multinational companies endogenously remain in or exit from joint ventures in sanctioned fields, attenuating the effects of technology and financial sanctions when they stay.

Using the model, I simulate exploration and development, production, abandonment timing, and government revenues under alternative sanction policies. The model is calibrated using data on the asset portfolios of sanctioned Russian firms, and sanction impact parameters are disciplined by causal estimates from the 2014 natural experiment. Model estimates suggest that technology and financial sanctions imposed on Russian oil companies in 2014 will accelerate average field abandonment by 18.4% (3.7 years) and reduce Russian government oil and gas revenues by 3.4% (US$32.5 billion) over 20 years. Requiring multinationals to exit from sanctioned joint ventures in 2014 would have reduced government oil revenues by a further US$1.6 billion over 20 years, but at a discounted cost of US$63 billion in foregone multinational profits over the same horizon – an example of sanction-induced "friendly fire." Finally, I find that coupling the 2014 input sanctions with a US$60 output price cap would have reduced production by 12% and government oil revenues by 32% over 20 years.

1.1 Related Literature and Contributions

Much of the research on sanctions has focused on macroeconomic and country-level outcomes. For instance, Bianchi and Sosa-Padilla (2023) and Sanusi et al. (2023) demonstrate how sanctions may weaken the reserve currency status of the US dollar. Sanctions can exert countervailing positive and negative effects on targeted countries' exchange rates (Itskhoki and Mukhin, 2025; Lorenzoni and Werning, 2023), reduce GDP growth (Kwon, 2023), increase food insecurity (Afesorgbor, 2019), and prompt authoritarian governments to increase oppression (Oechslin, 2014; Peksen and Drury, 2010). Reviewing 32 cross-country studies of sanction impacts, Rodríguez (2023) concludes that sanctions typically reduce per capita income and increase mortality, poverty, and inequality in targeted countries. Another large literature studies sanction impacts on trade (Dai et al., 2021; Crozet and Hinz, 2020; Haidar, 2017), generally finding that sanctions exert significant negative effects on trade flows.

Country and sector-level studies of sanction impacts face methodological challenges due to the endogeneity of sanction application and confounding between sanctions and other events affecting the country (Felbermayr et al., 2024). Studies at this level face further limitations because most sanctions are imposed on firms and organizations, which may adapt in ways that do not appear in aggregate statistics. In response to these limitations, studies increasingly analyze sanction impacts at the firm level. Ahn and Ludema (2020) find that Russian firms targeted by sanctions after 2014 experienced significant losses in revenues, assets, and employment relative to non-sanctioned firms, while Nigmatulina (2023) finds that sanctioned Russian firms *increased* revenues due to preferential access to government credit. Mamonov et al. (2021) show Russian banks reduced foreign assets and liabilities after being sanctioned. Korovkin and Makarin (2023) find that firms in areas of Ukraine with fewer ethnic Russians experienced deeper reductions in trade with Russia after 2014, showing ethnic networks moderate sanction impacts. I contribute to this literature by measuring dynamic within-firm adaptation to sanctions across heterogeneous asset portfolios. Field-level panel data allow me to measure novel dimensions of firm adaptation, including investments, asset divestment, and joint venture partnerships. Specific features of the oil sector, such as clearly defined field-level reserves and exploration investments (analogous to inventories and R&D in other sectors) enable credible analysis of intertemporal optimization under sanction-induced distortions.[3]

This study contributes most immediately to literature on the efficacy of sanctions against Russia following its 2014 and 2022 invasions of Ukraine. Nguyen and Do (2021) find that trade sanctions imposed on Russia after 2014 reduced oil exports by 37%. Shingal (2024) shows that some of this reduction resulted from trade diversion toward domestic producers. Trade sanctions also provoked reallocation of Russian gas exports from European to Chinese and Indian buyers (Sharma, 2024), which increased transportation costs (Spiro et al., 2024) and forced Russia to rely on a "shadow fleet" of uninsured tankers (Cardoso et al., 2025). Kilian et al. (2025) estimate that the EU embargo on Russian oil imposed after 2022 imposed a $32 per barrel discount on Russian oil exports, making this policy substantially more effective than the price cap. I contribute to this body of evidence, and to ongoing policy

[3]There is a small literature focused on sub-national spatial impacts of sanctions. Lee (2014) shows that sanctions on North Korea increased night-time light intensity in the capital and decreased night lights in rural areas – exacerbating regional inequalities. Arbatli and Gomtsyan (2021) show night lights in Hezbollah-controlled villages in Lebanon decreased disproportionately after sanctions were imposed on Iran, Hezbollah's sponsor. I contribute to this literature by exploring sanction impacts at the oil field level using night-time lights and gas flaring. My findings reveal positive local economic spillovers from the sanction-induced production increase, as well as increased gas flaring after 2022 – potentially due to loss of the European gas export market in this year.

debates (Johnson and Wolfram, 2024; Berman, 2024), by providing the first field-level empirical assessment of sanction impacts on Russia's critically important oil industry. Results inform current debates by reconciling the apparent failure of sanctions to curtail current production with confirmation of damage to long-term production capacity caused by deep cuts in exploration, field abandonment, and multinational exit from joint ventures.

Finally, this paper contributes to several broader strands of literature in economics. Theoretically, it incorporates sanction distortions into a dynamic model of resource extraction, building on the classic Hotelling model (Hotelling, 1931; Pindyck, 1978) while accounting for realistic exploration and production constraints emphasized by Anderson et al. (2018) and Bornstein et al. (2023). Moreover, the paper connects to literature on multi-establishment firms and within-firm resource allocation (Giroud and Mueller, 2019; Maksimovic and Phillips, 2002). My findings reveal how sanctioned firms adjust exploration, production, and ownership across establishments (i.e., fields) based on field characteristics. By analyzing impacts of multinational exit from joint ventures, I extend Kellogg (2011)'s evidence on relationship-specific productivity gains from interfirm partnerships in the oil industry, revealing an additional source of relationship-specific value: access through multinationals to advanced technology and financing that sanctioned firms cannot access on their own. Finally, my results confirm findings in Ahlvik et al. (2024), who show that oil production taxes reduce exploration but not production. I extend their framework by incorporating non-price supply-side mechanisms, namely technology and financial sanctions.

2 Context: Sanctions on Russian Oil Companies

Sanctions affected around 4% of country-pairs between 1950 and 1990, then proliferated rapidly to cover 12% of country pairs and 27% of global trade flows by 2023 – an all time high (Felbermayr et al., 2024).[4] In recent decades, sanctions have evolved from sweeping country-level embargoes, such as the United States' trade embargo on Cuba, to targeted "smart

[4]Heavily sanctioned countries include a disproportionate number of oil dependent economies, including (with oil as percentages of GDP and exports in 2024 reported in parentheses) Iraq (46%, 99%), Libya (40%, 95%), Angola (33%, 96%), Yemen (25%, 80%), Azerbaijan (24%, 86%), Iran (22%, 76%), Venezuela (18%, 84%), Turkmenistan (14%, 70%), Nigeria (12%, 93%), Russia (8%, 56%), Egypt (7%, 34%), Sudan (6%, 63%), and Syria (6%, 58%) (World Bank, 2024).

sanctions" applying to specific entities, including individuals, organizations, and companies (Felbermayr et al., 2020). The OpenSanctions (2025) database listed 260,920 sanctioned entities in July 2025.

Sanctions on companies most often take the form of *input sanctions*, which restrict access to goods, services, and financing by penalizing third parties that transact with the target. Once a target is designated by a sanctioning authority such as the U.S. Treasury's Office of Foreign Assets Control (OFAC), input suppliers, financial institutions, and service providers risk legal or financial penalties for continued dealings with that entity. As a result, even firms from non-sanctioning countries may cease cooperation with sanctioned firms to avoid penalties or secondary sanctions (U.S. Department of the Treasury, 2024).[5]

Russia's invasion of Crimea and the eastern Donbas region of Ukraine in 2014 triggered a coordinated sanctions response from the United States and the European Union. A major component of this response was the imposition of input sanctions targeting Russia's oil and gas sector, which at the time generated approximately two-thirds of the country's export earnings and half of federal government revenues (Altiparmak et al., 2023). Six Russian oil and gas companies were targeted: Rosneft, Gazprom, Gazprom Neft, Lukoil, Novatek, and Surgutneftegaz (U.S. Department of the Treasury, 2014).[6] Restrictions placed on dealings with these companies included (i) a *ban on provision of long-term financing*, (ii) *export controls on advanced technologies* required for Arctic, deepwater offshore, and shale exploration and development, and (iii) *limits on new high-tech joint ventures* with Western firms – though existing partnerships were allowed to continue (Mäe, 2016).

Financial Sanctions: Restrictions on Western financing constrained the ability of targeted oil companies to access foreign loans, raising borrowing costs and limiting capacity to pursue capital-intensive or long-term projects, such as offshore Arctic exploration (Coote, 2017). Sanctioned firms reportedly adapted to this disruption by shifting efforts toward production

[5]Sanctions on oil companies may also target their *outputs*, either through an outright purchase ban or a price cap that permits sales only below a predetermined price threshold. The aim of an output price cap is to reduce sanctioned companies' revenues while minimizing disruptions to global supply (Johnson et al., 2023). Such measures require broad international coordination and are typically enforced via financial and insurance channels – for example, by prohibiting shipping insurers from covering cargo sold above the cap (Cardoso et al., 2025).

[6]Over 200 oil fields were directly held by the Russian government as of 2013. I include these in the treated (i.e., sanctioned) group and leave them out in a robustness check.

in already-developed fields and seeking alternative funding sources, including domestic banks, the Russian government, and lenders in China and India (Altiparmak et al., 2023).

Technology Sanctions: Export restrictions on advanced oilfield technologies resulted in significant delays and disruptions across new oil and gas projects. Prior to the 2014 sanctions, Russian oil companies reportedly imported 50% of their high-tech oilfield equipment and 80% of software from Western countries, with these shares rising to 80% and 90%, respectively, for sub-seabed deposits (Mäe, 2016). Russian oil companies were also almost entirely dependent on Western suppliers for fracking chemicals, disrupting a nascent fracking industry focused on Russia's Bazhenov shale formation (Panin, 2014). Substitution of technologies from China or other sanction non-compliant countries proved challenging, as many of the technologies sourced from these countries also included Western components or could not replace Western inputs in specific technology niches. Despite government efforts to promote local upstream input production, domestic replacements for many parts, equipment, and software were in many cases unavailable or of insufficient quality (Panin, 2014).

Multinational Partnerships: Sanctions also led some Western oil companies to suspend or cancel joint ventures with sanctioned companies in several fields (Mäe, 2016). However, many international partnerships with sanctioned Russian firms persisted after 2014. For instance, British Petroleum retained the 19.75% equity stake in Rosneft it acquired in 2013 (Coote, 2017; Mäe, 2016).[7]

3 Data and Descriptive Evidence

The primary data source for this study is the Upstream Solution dataset provided by Rystad Energy (2025), an energy research company. Data include annual measures of reserves,

[7] Additional sanctions imposed following Russia's invasion of Ukraine in 2022 exceeded the scope of the 2014 measures, including restrictions on payment systems, joint ventures, an EU embargo on Russian oil imports, and a coordinated G7 price cap on seaborne Russian crude oil (Kilian et al., 2025; Milov, 2024). The decoupling of Russian pipeline gas from the European market resulted in significant loss of export income, especially for state-owned gas company, Gazprom (Gross and Stelzenmüller, 2024). Post-2022 sanctions triggered more extensive exit of Western energy companies from Russia than occurred in 2014. BP divested its 19.75% stake in Rosneft, declaring a US$25.5 billion loss on its Russian holdings. Equinor transferred four joint ventures to Rosneft, ExxonMobil abandoned a US$4 billion investment in the Sakhalin-1 project, and Shell wrote off its stake in Sakhalin-2 and sold additional business segments to Lukoil (Rystad Energy, 2025; Reuters, 2022).

production of oil and gas, capital expenditures, operating expenditures, exploration expenditures, government royalty and tax payments, and ownership stakes for 106,474 fields globally between 1970-2024.[8] Data also include field characteristics such as location, well depth, discovery date, breakeven price at time of discovery, basin, and depositional geography, as well as company characteristics such as headquarters location and size.[9] Headquarters location allows me to distinguish between multinational and local firms, and time-varying participation stakes allow me to track field ownership changes over time.

Sanctioned oil companies are identified from contemporaneous government announcements (e.g., U.S. Department of the Treasury (2014)) and confirmed based on comprehensive lists of sanctioned entities from the U.S. Office of Foreign Assets Control (2024) and OpenSanctions (2025) before being matched against the universe of companies that ever appear as participants in oil and gas fields in Rystad Energy (2025). Using corporate tree data from S&P Global Market Intelligence (2024), I also identify all level-one subsidiaries of sanctioned firms, to which sanctions also apply. I define treatment at the *oil field level* based on whether or not a sanctioned company held an equity stake in the field in 2013 – the year prior to sanctions. See Section 4 for more detailed discussion of this treatment definition.

Finally, to measure the intensity of economic activity around sanctioned versus non-sanctioned oil fields, I intersect oil field boundary polygons (as well as 5km, 10km, and 20km buffers) with 1x1km gridded economic activity levels inferred annually from night-time light intensity, based on Chen et al. (2022). Night light intensity within oil field boundaries

[8]Rystad Energy data are considered to be high-quality and are frequently used in peer-reviewed studies focused on the oil industry, including Cardoso et al. (2025), Coulomb et al. (2025), Ahlvik et al. (2024), and Bornstein et al. (2023). To validate reliability of Rystad data for Russian oil fields during the study period, I plot binned scatterplots of key field-level outcomes from Rystad (oil and gas production, exploration and capital expenditures, operating expenditures, and government payments) against satellite-measured night light intensity within 5km of oil fields – which are collected from a separate data source (Chen et al., 2022). Insofar as increased field-level production and investments are associated with greater night light intensity, we should expect a significant positive correlation if the Rystad data are accurate. Reassuringly, as reported in Appendix Figure A1, there are strong positive correlations between night light intensity and production, E&D investment, operating expenditures, and government revenues from Russian oil fields.

[9]Monetary values are deflated to constant 2017 USD using the implicit price deflator from FRED. I aggregate production across product types into "barrels of oil equivalent" using standard conversions. To avoid endogeneity in the definition of high versus low-cost fields, I use time-invariant initial breakeven costs estimated at the time of each field's discovery. Oil and gas fields are typically owned through participation shares, which sum to 100% across participating companies. Fields also appear in the dataset when they have no companies attached but have some residual costs, in which case they are identified as inactive or abandoned.

serves as a proxy for direct production activities, while night light intensity in spatial buffers proxies for spillovers of economic activity into nearby towns and cities. I also intersect field polygons with gas flaring intensity (in billions of cubic meters, or BCM, from geo-coded point sources), from the Payne Institute for Public Policy (2024). Gas flaring is an indicator of low-quality technology or production practices, or lack of ability to store and pipe gas for commercialization.

3.1 Descriptive Evidence

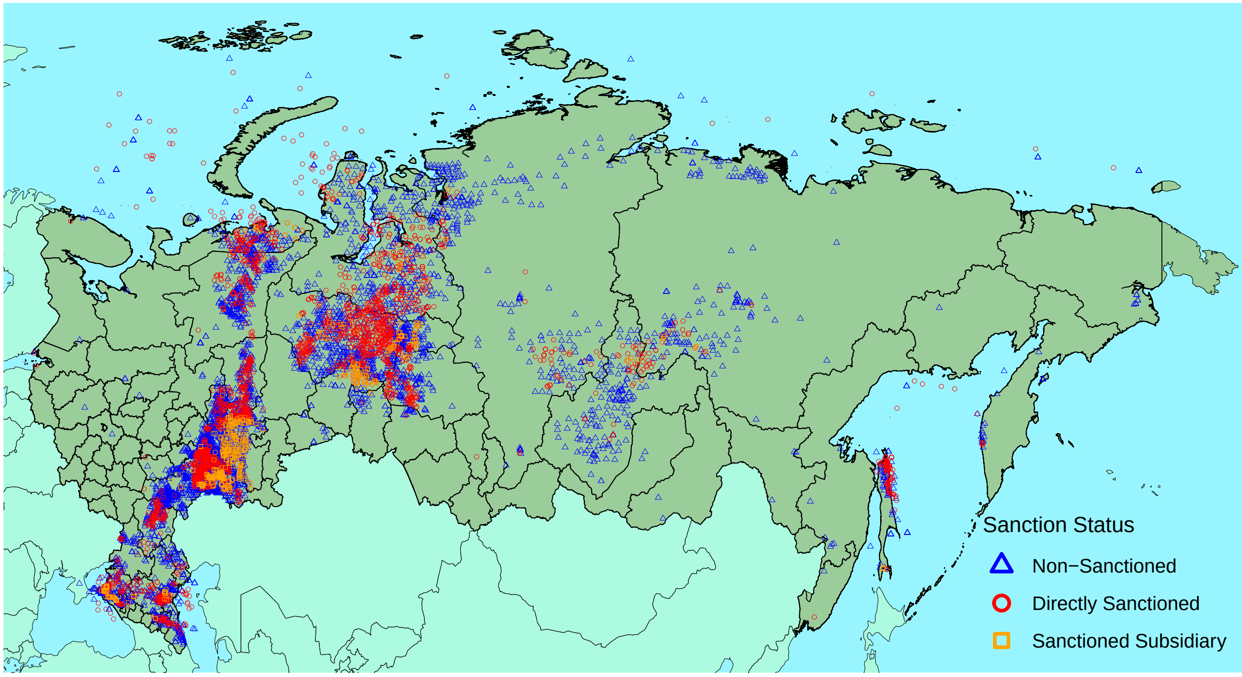
Figure 1 maps the location of oil and gas fields operated by sanctioned companies, subsidiaries of sanctioned companies, and non-sanctioned companies within Russia as of 2014. From the map, it is evident that sanctioned and non-sanctioned fields are both widely distributed and share common spatial support across regions.[10]

Characteristics of sanctioned and non-sanctioned Russian fields are summarized in Appendix Table B1. Fields held by sanctioned Russian oil companies are substantially larger on average than non-sanctioned fields, with higher average production (2.18 vs. 0.24 mmboe), reserves (72 vs. 10.4 mmboe), exploration investments (86 vs. 7.8 million USD), and government payments (38 vs. 3.1 million USD). This is to be expected given that sanctions primarily targeted several of Russia's largest oil companies. Sanctioned firms also operated a higher share of offshore fields (4% of their portfolio versus 1% for non-sanctioned companies), which is reflected in higher average baseline breakeven costs (US$61.6 vs. US$56.0 for non-sanctioned companies).

Figure 2 plots means of key outcomes between 2000-2024 for fields held by sanctioned and non-sanctioned companies, showing that – while different in levels – trends in production, exploration, reserves, and government payments were roughly comparable for several years

[10] Appendix Figure A2 plots the number of Russian fields operated by each company in 2013. Sanctioned companies included major players like Rosneft (1,121 fields), Lukoil (835 fields), and Gazprom (374 fields), as well as fields held directly by the Russian government (291 fields), the moderately-sized Surgutneftegas (216 fields), and the smaller Novatek (80 fields). Non-sanctioned fields display less concentrated ownership, held by moderately-sized firms like Bashneft (271 fields), Russneft (198 fields), Tatneft (184 fields), and dozens of smaller companies operating just a few fields. The largest category of non-sanctioned fields (3,263) had no registered owner in 2013, indicating inactivity (though these fields may have been operated by a company before or after this year). Major multinational participants like BP (which acquired a 19.75% of all Rosneft fields in 2013) do not appear in the figure because they were minority participants rather than operators.

Figure 1: Russian Oil and Gas Fields by 2014 Sanction Status



Note: Field locations are from Rystad Energy (2025). Sanctioned fields are defined as those operated by Gazprom, Gazprom Neft, Lukoil, Rosneft, Novatek, Surgutneftegas, or the Russian Government as of 2013. Fields operated by level-one subsidiaries of these companies, identified based on corporate trees reported in S&P Global Market Intelligence (2024), are also noted on the map.

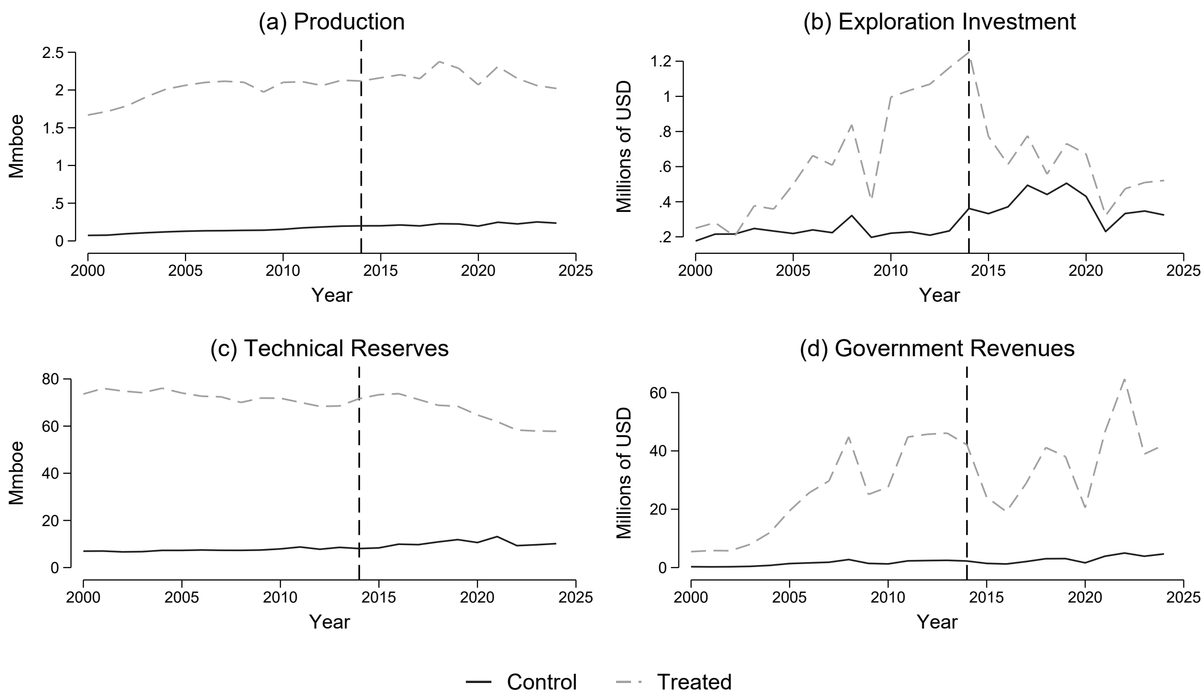
leading up to the 2014 sanctions (though they varied substantially in some earlier years). After 2014, production in sanctioned fields remained relatively stable, exploration collapsed, reserves declined, and government payments continued at similar levels, though with high year-to-year volatility resulting from variations in the world oil price.[11]

Large level differences in mean outcomes may raise concerns about lack of common support between sanctioned and non-sanctioned groups. Three points alleviate these concerns. First, empirical specifications (detailed in Section 4) include field fixed effects, absorbing level differences and identifying effects from within-field variation over time. Second, despite large differences in outcome means, there is substantial overlap across outcome distributions.

[11]Figure 2b shows a modest increase in exploration investment among non-sanctioned fields after 2014, suggesting potential capital reallocation from sanctioned to non-sanctioned firms. This pattern has two implications. First, such spillovers could bias estimated treatment effects on exploration upward. I address this concern in a robustness check by bounding the magnitude of potential spillovers and estimating spillover-corrected effects. Second, if non-sanctioned firms are less productive at converting exploration investment into reserves, such reallocation would generate aggregate efficiency losses. I quantify this misallocation in Section 5.5.

Appendix Figure A3 plots kernel densities of key variables for sanctioned and non-sanctioned fields. While sanctioned fields feature a longer right tail for some variables (resulting in the higher means in Figure 2), there is substantial overlap throughout most of the distribution. Hellinger distances measuring distributional similarity range from 0.11 to 0.24 across all variables. Third, as described in Section 5.5, I conduct a robustness check restricting the sample to fields that match on baseline characteristics prior to estimating event studies: 96% of fields survive the matching procedure and results are strongly robust.

Figure 2: Mean Field-Level Outcomes (2000-2024)



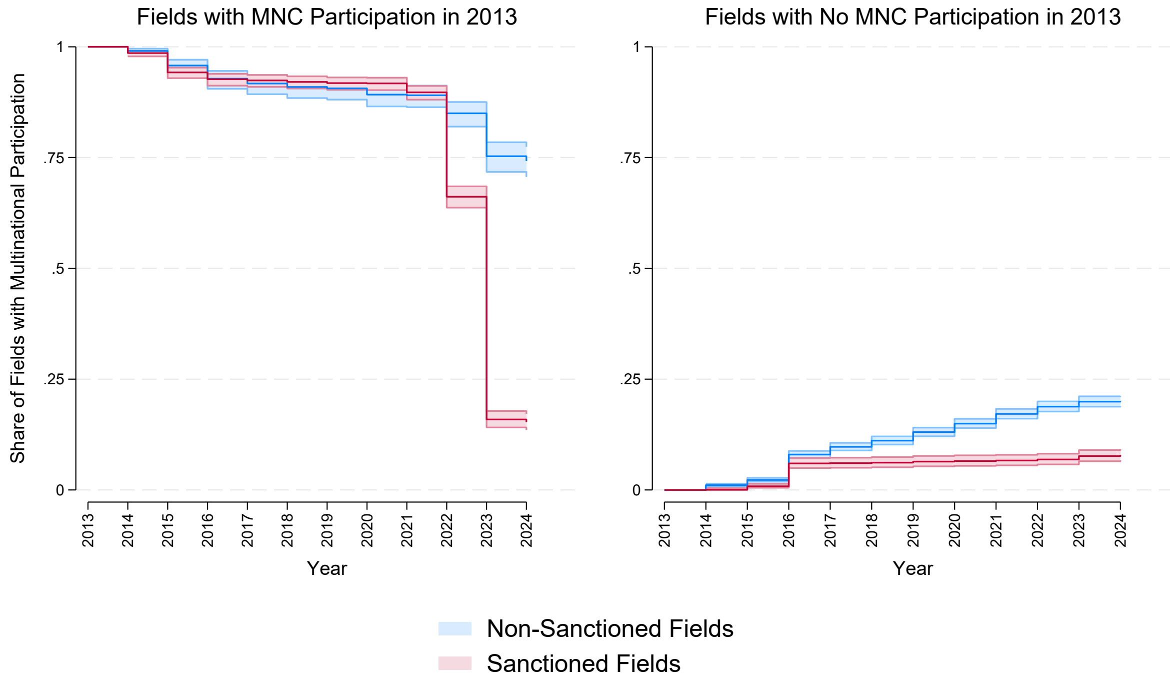
Note: Treated fields are defined as those with a non-zero equity stake held by a sanctioned company in 2013. Control fields are all fields with no sanctioned participant in 2013. The panel is strongly balanced. Production and technical reserves are reported in millions of barrels of oil equivalent. Exploration investment and government revenues are reported in millions of constant 2017 USD.

Sanctioned firms can also engage in field-level ownership changes, such as divestment to subsidiaries or to other firms (which may be local or multinational) or asset abandonment if no buyer can be found. In theory, ownership switching could be a sanction dodging strategy if sanction restrictions follow companies rather than fields. In practice, transaction costs or owner incentives may limit this strategy. Appendix Figure A4 plots the number of ownership switches each year for fields held by sanctioned firms as of 2013. Several patterns emerge. First, many sanctioned fields were acquired in the preceding decade, with 1,195 fields transitioning to to-be-sanctioned company ownership between 2004 and 2013. Second, 197 sanctioned fields switched to inactivity (i.e., ceased operations with no identified owner) in the three years following the 2014 sanctions. Third, 269 fields switched from sanctioned to non-sanctioned Russian ownership following the 2022 sanctions. This sudden surge is indicative of sanction evasion through ownership restructuring. Notably, there was minimal switching from sanctioned company ownership to sanctioned subsidiaries, multinationals, or non-sanctioned Russian companies prior to 2022. The emergence of large-scale ownership transfers to non-sanctioned Russian firms after 2022 suggests strategic adaptation: sanctioned firms may have learned evasion strategies over time and deployed them in 2022. From a causal inference perspective, these post-2022 evasion tactics do not threaten identification of 2014 sanction effects through 2021.

To gauge multinational (MNC) exit from Russian oil fields in response to sanctions, Figure 3a plots MNC participation for the sub-sample of fields with MNC involvement in 2013, distinguishing between fields held by sanctioned and non-sanctioned companies. Following the 2014 sanctions, MNC participation declined only slightly in both groups, with approximately 90% of fields retaining MNC involvement through 2021. In contrast, after Russia's invasion of Ukraine in 2022, MNC participation in sanctioned fields fell sharply – from 90% in 2021 to 20% by 2024 – while decreasing more moderately, from 90% to 75%, in non-sanctioned fields. These patterns indicate that 2014 sanctions did not trigger substantial divestment by MNCs, whereas 2022 sanctions prompted a rapid exit from sanctioned assets.

To gauge MNC entry, Figure 3b plots MNC participation in the sub-sample of Russian fields with no MNC participation in 2013. MNC entry into sanctioned fields after 2014 was substantially lower than entry into non-sanctioned fields, with only 10% of fields experiencing MNC entry by 2024, relative to 22% of non-sanctioned fields. This pattern suggests that, while the 2014 sanctions did not induce widespread divestment from existing ventures, they effectively discouraged new ventures, consistent with sanction provisions that restricted formation of new joint ventures without mandating withdrawal from pre-existing ones.

Figure 3: MNC Participation in Sanctioned Fields



Note: Panel (a) reports the share of fields with MNC participation for the subset of fields with non-zero MNC participation as of 2013, with results plotted separately for sanctioned (red) and non-sanctioned (blue) fields. Panel (b) reports analogous results for the subset of fields with no MNC participation as of 2013.

4 Empirical Strategy and Identification

Using a balanced panel of 8,313 Russian oil and gas fields observed annually between 2000-2024, I estimate event studies around the year of sanction application (2014), where treated fields are defined as those with an ownership stake held by a sanctioned company in 2013, and control fields are those with no participation by a sanctioned company in 2013.[12] Specifically, I regress outcome Y_{ict} in field i and year t, which was operated by company c in the year prior to sanctions, on field and year fixed effects (δ_i and γ_t, respectively) and relative time indicators (T_{ict}) around the first year in which company c was sanctioned:

$$Y_{ict} = \delta_i + \gamma_t + \sum_{t \neq 2013} \beta_t T_{ict} + \epsilon_{ict}$$

[12]For robustness, I use broader and narrower definitions of sanction treatment. The broader definition includes level-1 subsidiaries of sanctioned companies, since these are also technically subject to sanction penalties. The narrower definition restricts the treated sample to fields with a majority ($\geq 50\%$) stake held by a sanctioned company in 2013.

Standard errors are clustered at the level of treatment (i.e., the company operating the field in year $t - 1$), following Abadie et al. (2022), and estimation uses the estimator developed in Callaway and Sant'Anna (2021) to avoid bias from heterogeneous treatment effects. In the preferred specification, outcomes are transformed using the inverse hyperbolic sine function to reduce the influence of extreme outliers while accommodating zero-value observations (Bellemare and Wichman, 2019). Following Chen and Roth (2023), robustness checks use alternative transformations or untransformed outcomes. I also conduct heterogeneity analyses by splitting the sample and re-estimating event studies separately by sub-group, including high and low-breakeven cost (defined as fields with breakeven cost at the time of discovery greater than or less than the median value for Russia – US$58.2), offshore and conventional onshore location, and development stage.

4.1 Identification

Causal inference relies on several identifying arguments and assumptions. First, Russia's 2014 annexation of Crimea was a localized conflict that only impacted the vast majority of Russia's territory and economy indirectly by triggering sanctions on specific companies. This event was plausibly exogenous to field-level trends and characteristics, and has been used in previous studies to identify sanction impacts (Korovkin and Makarin, 2023; Nigmatulina, 2023; Ahn and Ludema, 2020).

Field-level treatment is defined by the identity of the company operating each field in the year prior to sanctions, ensuring that treatment status is not determined by post-sanction outcomes. Field-level ownership is allowed to vary flexibly after sanctions are applied, since this is an endogenous outcome. The fully balanced panel ensures there is no selection of fields into or out of the sample. Clustering standard errors by the (time-invariant) operating company in year $t - 1$ accounts for potential correlation in shocks and outcomes across fields managed by the same firm.

Inclusion of field fixed effects absorbs all time-invariant field-level characteristics (e.g., location, geology, initial reserve levels), while year fixed effects absorb common shocks affecting all fields across years (e.g., global oil prices). Comparing outcomes *within* Russia between sanctioned and non-sanctioned fields avoids confounding due to potential country-level effects of sanctions (i.e., reputational damage for multinationals doing business in Russia regardless of whether it is with a sanctioned company).

There may be concerns that companies targeted with sanctions were selected endogenously due to their strategic importance for the government or close political connections with political leaders. Estimating dynamic treatment effects around the year of sanction application allows for inspection of pre-trends and potential anticipation effects, which could occur if fields held by sanctioned firms were on systematically different trajectories from non-sanctioned fields, or if politically-connected firms were able to anticipate the 2014 conflict.[13]

Identification is further facilitated by common support between treated and control fields. As discussed in Section 3, distributional overlap on key variables is verified in Appendix Figure A3 and matching on pre-treatment characteristics retains 96% of fields. Results are robust to restricting the sample to matched fields.

Finally, identification of unbiased treatment effects requires compliance with the Stable Unit Treatment Value Assumption (SUTVA), i.e., the absence of spillovers between treated and control groups. Figure 2 shows no visible jumps in mean control outcomes after 2014 with the exception of exploration investment, which increased slightly. This pattern could reflect reallocation of exploration capital from sanctioned projects to non-sanctioned projects as a result of investors seeking to avoid costly sanction-induced restrictions. Capital reallocation would bias estimated treatment effects upward. Several factors limit the scope for such reallocation. First, exploration activity cannot be seamlessly shifted across projects and firms due to geographic, infrastructure, and relational constraints. Second, firms have heterogeneous exploration capabilities – a small non-sanctioned company managing mature onshore fields cannot realistically undertake deepwater Arctic exploration, even if capital is made available. Third, sanctioned fields possess substantially higher potential reserves, possibly making them more attractive exploration targets even under sanctions. In Section 5.5, I quantify potential spillovers in exploration investment to provide an upper bound on bias from capital reallocation.

[13] In the case of Russia, sanctioned companies included some with close ties to Russian leaders (e.g., state-owned Rosneft and Gazprom), as well as Lukoil, a privately-held company that is widely perceived to have weaker ties to the government, and Surgutneftegas, a privately-held, publicly traded company (Altiparmak et al., 2023). As a robustness check, I estimate leave-one-out event studies that exclude sanctioned companies one by one to assess sensitivity to individual firms, and find that results are strongly robust.

In contrast to the clean natural experiment created by Russia's 2014 invasion of Crimea and eastern Ukraine, identifying the effects of sanctions following Russia's 2022 invasion is more challenging. The 2022 sanctions included across-the-board restrictions on Russian oil sales via the price cap and EU import embargo (affecting both sanctioned and non-sanctioned companies), as well as broader shocks to the economy, such as macroeconomic instability, loss of access to Western payment systems, and labor market disruptions from military mobilization (Rybakova, 2025). Ukrainian drone strikes on oil infrastructure in Russia have also directly affected the sector (Siegle, Siegle). These overlapping factors complicate efforts to disentangle the impact of sanctions from other concurrent shocks after 2022. Consequently, I interpret estimates through 2021 as causal effects of the 2014 sanctions, while treating post-2022 results as descriptive. Readers interested in post-2022 patterns should interpret these coefficients with caution given confounding factors.

5 Results

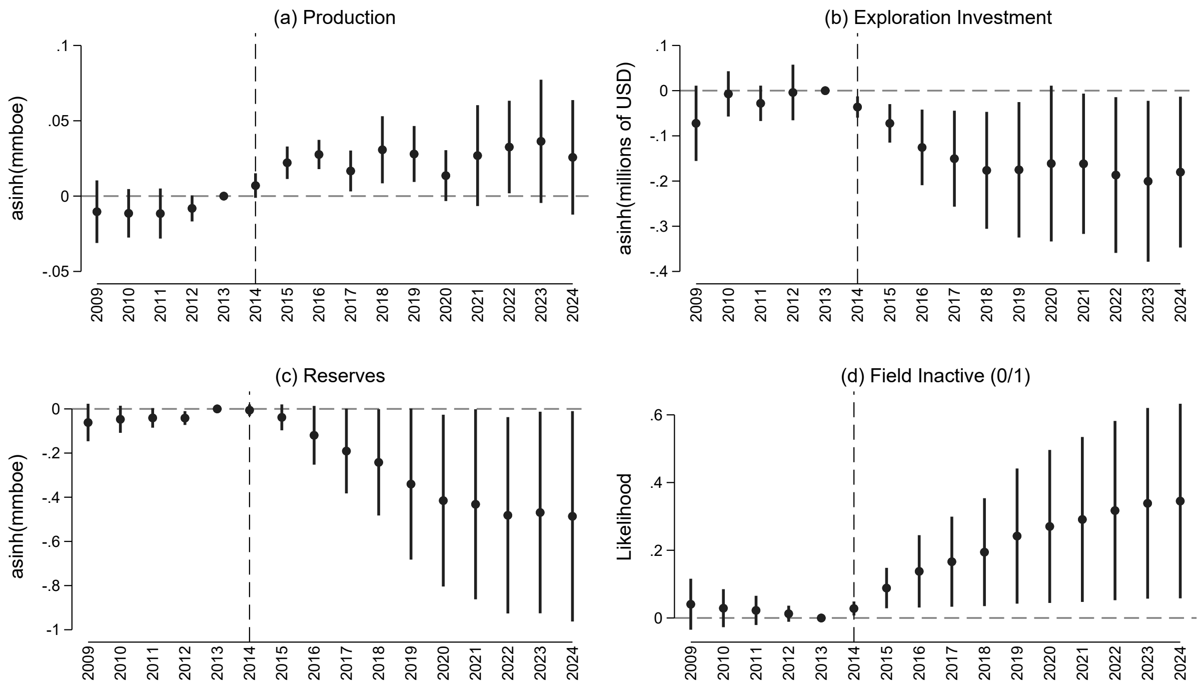
5.1 Main Outcomes

Primary field-level event study estimates are presented in Figure 4, which shows impacts of the 2014 sanctions on (a) oil and gas production volume, (b) exploration investment, (c) technical reserves, and (d) field activity status. Tables reporting coefficient estimates, standard errors, and sample statistics corresponding to all figures in this section are reported in Appendix Section B.

Results indicate that production in sanctioned and non-sanctioned fields evolved along statistically similar trajectories in the five years prior to sanctions, consistent with the identifying parallel pre-trends assumption. After sanctions were imposed in 2014, oil equivalent production increased significantly in sanctioned fields relative to controls, reaching +2.8%, or +44,000 barrels per field-year, in 2016.[14] Average production in sanctioned fields fell back into line with non-sanctioned fields by 2020 before rising again in 2022 – coinciding with

[14]Continuous outcomes are transformed using the inverse hyperbolic sine function and semi-elasticities are computed as $100 \times (e^{\hat{\beta}} - 1)$, following Bellemare and Wichman (2019). Level interpretations are obtained from separate event study estimations using outcomes expressed in untransformed levels, which are reported in Appendix Table B10.

Figure 4: Sanction Impacts on Key Field-Level Outcomes



Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

additional sanctions in that year. Exploration investment in sanctioned fields also evolved in parallel with non-sanctioned fields prior to 2014, then declined significantly after sanctions were imposed, with an average reduction of 11.8% (US$124,000/field-year) by 2016 and 15.0% (US$149,000) by 2021. Technical reserves were also evolving in parallel prior to 2014 and declined significantly in sanctioned fields after this year, with a reduction of 35.1%, or 1.85 million barrels of oil equivalent, by 2021. Finally, the likelihood that a field was inactive (i.e., not held by any company) rose significantly in sanctioned fields after 2014, reaching an increase of 29.1 percentage points by 2021.[15] In sum, sanctioned oil companies

[15] Appendix Figure A5 presents results for additional outcomes, including capex, opex, and government revenues. Capex exhibits non-parallel pre-trends for years prior to 2014, but is significantly lower in sanctioned fields after 2014, in line with reduced future-focused development. In contrast, opex remains flat, in line with stable or increased current production. Government revenues increase significantly, though noisily, in line with increased production.

significantly increased oil and gas production for several years following the 2014 sanctions while abandoning fields and cutting investments in exploration to generate new reserves – leading to reserve depletion.

5.2 Heterogeneity by Field Characteristics

I next assess heterogeneity in sanction impacts by field characteristic. Appendix Figures A6 and A7 report event studies for sub-samples of fields with below and above-median breakeven price at time of discovery (a proxy for technical complexity and development requirements). Results show that the short-term production increase in sanctioned fields occurred in both low-cost and high-cost fields. In contrast, decreases in exploration investment and reserves were concentrated overwhelmingly in high-cost fields, where exploration declined by 28.4% and reserves declined by a striking 60.3% by 2021. These effects are likely due to the design of the 2014 sanctions, which specifically targeted critical technology inputs and financing required for exploration and development of new, technologically complex fields.

Splitting the sample by segment (i.e., conventional versus offshore fields) also reveals substantial heterogeneity in sanction impacts, albeit with some non-parallel pre-trends (Appendix Figures A8 and A9). While production from sanctioned fields increased significantly in both segments for several years following 2014, the increase was much larger in offshore fields (+16.3% versus +2.2% by 2019), likely because their larger size enabled larger production ramp-ups from already-producing fields. Exploration investment remained largely unchanged in onshore fields, but fell by 78.4% in offshore fields by 2021. Likewise, while reserve levels declined by 34.9% in conventional onshore fields by 2021, they declined by 67.9% in offshore fields, in line with increased production and decreased exploration. Finally, sanctioned offshore fields were 62.5p.p more likely to be abandoned than non-sanctioned offshore fields by 2024. Similarly to results for high and low-cost fields, these findings align with the design of 2014 sanctions. Offshore production requires advanced technologies – for which Russian oil companies depended on Western imports – and long-term financing to cover years of capital investments prior to production. Loss of access to these inputs had a devastating effect on reserve creation in sanctioned offshore fields.

Finally, I estimate event studies separately for unexplored fields (i.e., no discovery by

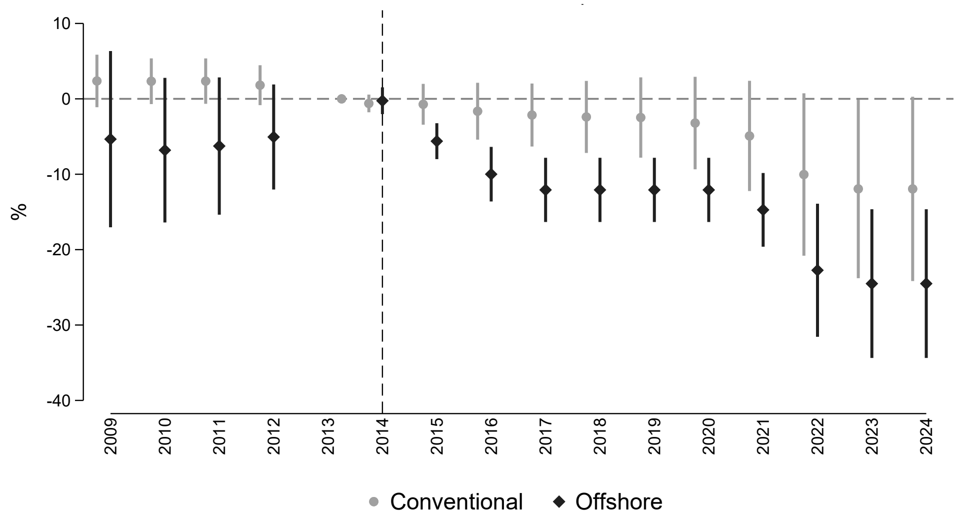
2013), recently explored fields (less than 10 years post-discovery), and mature fields (more than 10 years post-discovery). Results are reported in Appendix Figures A10 and A11. Production growth in sanctioned fields occurred primarily in the intermediate-age locations where discoveries were made in the decade preceding 2013. Opex and government revenues also increased in these fields, corresponding with increased production effort. In contrast, declines in exploration, capex, and reserves, as well as increased field abandonment, were concentrated in pre-discovery fields – precisely those that required the most advanced technologies and financing to develop. The positive production response in recently discovered fields is intuitive: these had likely already received the technology and capital inputs later blocked by 2014 sanctions, but unlike mature fields, had not yet been depleted.

5.3 Field Ownership Outcomes

Sanctions may also change asset ownership patterns. Companies may divest from fields if the net present value of future production turns negative under sanctions – as captured in the field inactivity indicator reported above. Companies may also pass off sanctioned assets to subsidiaries in an attempt to evade sanctions, or seek out new joint venture partners from non-sanction-compliant countries. Finally, multinational companies (MNCs) may exit joint ventures in sanctioned fields.

Figure 5 shows the effect of sanctions on MNC participation in sanctioned fields, split between conventional and offshore fields. Results indicate that rates of MNC participation in sanctioned fields evolved in parallel to non-sanctioned fields prior to 2013. After sanctions were imposed in 2014, MNC participation began to decline, with this effect concentrated in offshore fields. In this segment, average MNC participation declined by 14.7% by 2021, and by 24.5% by 2024. A large drop in MNC participation in sanctioned fields can be observed in 2022, when Russia's invasion of Ukraine triggered additional sanctions and heightened public pressure for MNCs to divest from Russian assets. MNC exit from offshore fields after 2014 was not prompted by any specific requirement, given that the 2014 sanction policy allowed existing partnerships with sanctioned entities to persist. Instead, MNC exit likely reflects technology and financing restrictions targeting offshore exploration and development, which

Figure 5: Sanction Impacts on Multinational Participation, by Segment



Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcome is defined as the percentage of a field's ownership held by countries headquartered outside of Russia. Event studies are estimated separately for conventional onshore and offshore fields.

increased costs and compliance risks for MNCs.[16]

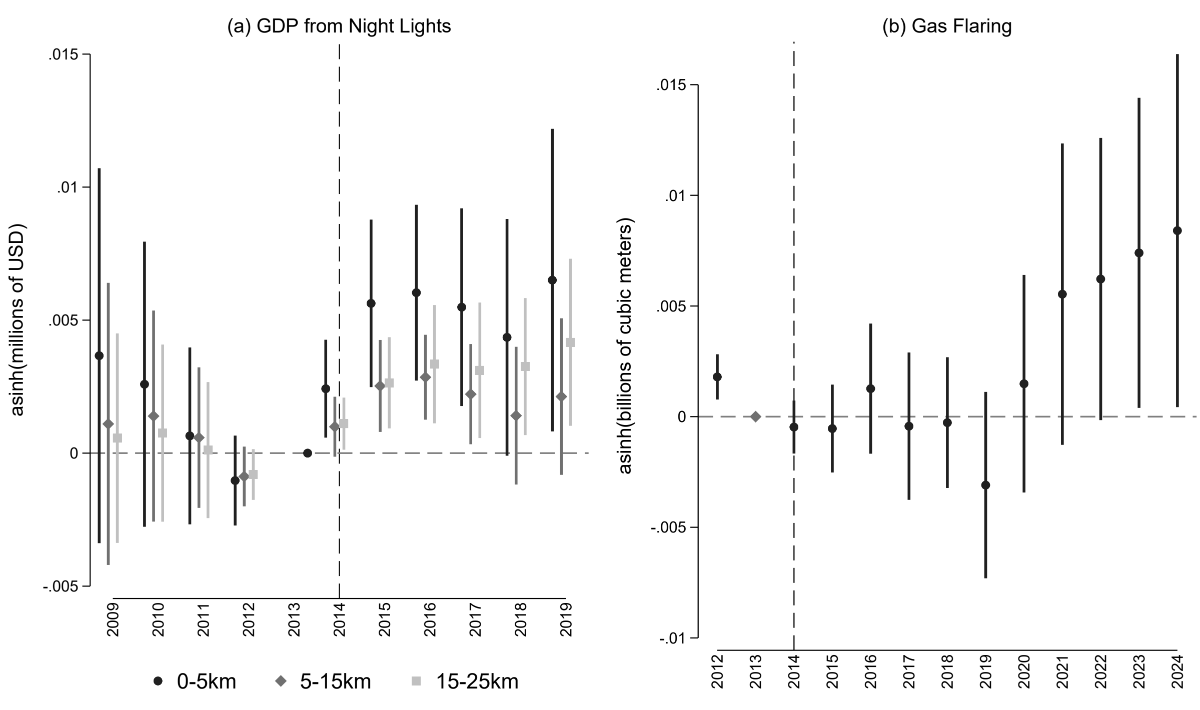
In Appendix Figure A14, I analyze heterogeneity in MNC participation by headquarters location. Specifically, I re-estimate the MNC participation event study separately for fields with MNCs headquartered in the EU or OECD (broadly corresponding to sanction-compliant countries) versus fields with MNCs headquartered elsewhere. Results indicate that participation by EU/OECD-based MNCs in sanctioned fields was unaffected by the 2014 sanctions, but declined sharply after 2022. MNC participation by non-EU/OECD-based companies trends gradually downward after 2014, but effects are not statistically distinguishable from zero and participation does not exhibit the same sharp drop after 2022, indicating that companies based outside the EU/OECD did not respond to pressures to divest from Russian assets (but also did not come in to replace exiting Western firms)

[16]An event study of participation by subsidiaries of sanctioned companies in sanctioned assets is shown in Appendix Figure A12. Results indicate that the 2014 sanctions had no statistically measurable effect on subsidiary participation. This aligns with sanction rules, whereby all beneficial subsidiaries of sanctioned entities are also sanctioned – removing any incentive to pass off ownership to subsidiaries as an evasion strategy. Appendix Figure A13 shows heterogeneity in the effect of sanctions on MNC participation by fields' breakeven cost, revealing no statistical differences along this dimension.

5.4 Geospatial Outcomes

Sanctions may also affect local economic activity around oil and gas fields. To assess this spatial dimension, I use 1km-by-1km data on GDP imputed from night-light intensity, from Chen et al. (2022), to measure economic activity in mutually exclusive bins of 0-5km around oil field centroids (i.e., direct production activities) and 5-15km and 15-25km (i.e., economic spillovers). Results, reported in Figure 6a, show local economic activity around sanctioned fields increased significantly for several years following sanction application, in line with increased production activities. Sanction effects on local economic activity peaked in 2016 at +0.6% within 5km of field centroids and +0.3% between 5-25km from fields, indicating substantial local spillovers from oil and gas production. These satellite-based results corroborate the post-2014 production increase observed in Rystad data, validating data quality.

Figure 6: Geospatial Outcomes



Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, estimated on a balanced field-year panel. Outcomes are transformed using the asinh function. GDP (in millions of USD) is summed across all 1x1km pixels within varying distance radii from oil field centroids. Gas flaring (in billions of cubic meters) is summed across all flaring point sources within oil field boundaries.

Gas flaring reflects operational and technological constraints, including inadequate infrastructure for gas capture and transport. Sanctions curtailed Russian companies' access to advanced technologies and induced exit of MNCs that had provided technology transfer. Moreover, following Russia's 2022 invasion of Ukraine, loss of European gas export markets left Russia with stranded gas that could not be redirected to alternative destinations in the short term. Figure 6 shows event study estimates for volumes of gas flaring (in billions of cubic meters) within Russian oil field boundary polygons, using data from the Payne Institute for Public Policy (2024) (available from 2012-2024). Results indicate that flaring remained largely unaffected by sanctions until 2022, after which it increased significantly (+0.80% by 2024). These results suggest that, from 2022 onward, loss of access to foreign technologies, MNC exit, and disconnection from gas export markets in Europe may have collectively resulted in increased gas flaring from sanctioned Russian fields.

5.5 Robustness Checks and Extensions

In this section, I assess the robustness of results presented above to alternative treatment definitions and outcome transformations, pre-treatment matching, additional fixed effects, and other sensitivity analyses and placebo tests.

Alternative Treatment Definitions: In my core specification, treated fields are defined as those with any participation by a sanctioned company in 2013. To assess the robustness of findings to this definition, I re-estimate core results using broader and narrower definitions of treatment, with results reported in Appendix Figures C1-C4. The broader definition includes all fields considered sanctioned in the main definition, as well as fields held by level-1 beneficial subsidiaries that are majority owned by sanctioned companies. This increases the sample of treated fields from 3,516 to 3,746. Results are strongly robust to this inclusion. The narrower definition restricts treated fields to those that are majority-operated by a sanctioned company in 2013. This definition reduces the treated sample to 2,148 fields. Results are very similar, but become statistically insignificant for some outcomes under the narrow definition because many fields treated by sanctions are included in the control group.

Alternative Outcome Transformations: Based on critiques by Chen and Roth (2023) of using either the inverse hyperbolic sine transformation or $ln(y+1)$ when outcomes can be zero, I re-estimate core specifications using untransformed continuous outcomes, winsorizing observations at the 2nd and 98th percentiles to reduce influence of extreme outliers. Results, presented in Appendix Table B10 and Figures C18-C19, are strongly robust. I use these results to interpret level effects of sanctions throughout the paper.[17] GDP from night-lights is almost always non-zero. As an alternative to asinh, I thus re-estimate the event study for this result using ln(y). Results, reported in Appendix Figure C20, are strongly robust. For gas flaring, I separately estimate the extensive margin (i.e., did a field-year have any flaring) and intensive margin (flaring volume conditional on positive flaring) (Appendix Figure C21). Results indicate that growth in flaring after 2021 came from the intensive margin.

Coarsened Exact Matching on Pre-Treatment Characteristics: Given differences in baseline levels between sanctioned and non-sanctioned fields, there may be concerns that fields are not comparable. To address this concern, I implement coarsened exact matching (Iacus et al., 2012) on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. I then re-estimate core specifications on the subsample of matched fields, including the CEM matching weight. Results for all outcomes and heterogeneity analyses, reported in Appendix Figures C5-C11, are strongly robust to this pre-treatment matching procedure

Sub-Basin, Oblast, and Breakeven Cost-by-Year Fixed Effects: Fields within the same sub-basin share infrastructure and are subject to common operational shocks, while fields in the same oblast face common political, economic, and regulatory conditions. Furthermore, sanctioned and non-sanctioned fields differ in their baseline cost structure, raising concern that estimated treatment effects could reflect differential exposure to price shocks rather than sanctions. I estimate event studies including sub-basin by year, oblast by year, and baseline breakeven-cost decile by year fixed effects to absorb these confounders, ensuring that esti-

[17] Field activity status is defined as 0/1 and MNC participation is defined as a percentage, so these outcomes do not require alternative transformations. To further assess sensitivity of core results to functional form, I re-estimate all continuous-outcome specifications using three alternative log transformations of the outcome variable: $\ln(y+0.01)$, $\ln(y+0.1)$, and $\ln(y+1)$. The resulting estimates, reported in Appendix Figure C17, differ somewhat in magnitude – as expected given the rescaling – but are highly stable in sign and statistical significance across specifications.

mated treatment effects are not driven by contemporaneous changes in local infrastructure, policy, economic conditions, or prices. These specifications use the TWFE estimator rather than Callaway and Sant'Anna, providing additional robustness to estimator choice. Results, reported in Appendix Figures C12-C14, are strongly robust.

Exclude Areas Bordering Ukraine: To avoid potential direct effects of the 2014 or 2022 conflicts, I omit Russian oblasts that share a border with Ukraine. Results are strongly robust to dropping these areas (Appendix Figure C15).

Leave-One-Company-Out Sensitivity Analysis: I re-estimate core event studies sequentially excluding each sanctioned company (grouping Gazprom and Gazprom Neft for brevity). This leave-one-out exercise tests whether results are disproportionately driven by any single firm. Across outcomes, estimated treatment effects (shown in Appendix Figure C16) remain similar in magnitude, sign, and statistical significance, confirming that findings reflect systematic responses to sanctions rather than idiosyncratic behavior of a particular company.

Placebo Tests: I conduct 100 placebo tests by randomly reassigning treatment to the same number of units as in the true sample, re-estimating event studies for each assignment, and plotting placebo coefficients alongside true treatment estimates. Results (Appendix Figure C22) show that true treatment effects are clearly distinct from the placebo distribution. Formally, I compute permutation p-values for each post-treatment year and outcome, defined as the share of placebo estimates exceeding the true estimate in absolute value. This provides exact finite-sample inference robust to the small number of treated clusters (MacKinnon and Webb, 2018). Results (Appendix Table C1) confirm that exploration investment and field inactivity are significant at $p < 0.01$ in all 11 post-treatment years, production in 9 of 11 years, and reserves in 10 of 11 years, indicating that main findings are highly unlikely to arise from random chance or correlation between sanction status and confounders.

Bounding Potential Spillovers in Exploration Investment: Figure 2 shows a modest increase in exploration investment in non-sanctioned fields following 2014, potentially indicating capital reallocation from sanctioned to non-sanctioned projects. This could represent an industry-wide sanction evasion tactic. To quantify the potential magnitude of this spillover, I first regress exploration investment on treatment status and a post-2014 indicator. This DiD estimate indicates that sanctions reduced exploration investment by 0.455 million USD per field-year (SE: 0.134, p-val: 0.002). I then calculate the control group's deviation from its 2009-2013 linear trend for each post-2014 year, which averages 0.165 million USD. Adjusting for this spillover yields a corrected treatment effect of -0.290 million USD, suggesting spillovers could account for up to 36% of the observed treatment effect. This represents an upper bound on spillover bias. I next estimate a spillover-corrected event study. For each post-treatment year, I calculate the control group's deviation from its pre-2014 linear trend and add this year-specific spillover to the corresponding event study coefficient. Appendix Figure C23 plots the results. Multiple post-treatment years remain significantly negative at the 10% level. The true causal impact of sanctions on exploration investment likely lies between the original and spillover-corrected bounds.

Capital Misallocation: To assess efficiency consequences of reallocating exploration investment from sanctioned to non-sanctioned firms, I estimate reserve creation per dollar of E&D investment for each firm type, following Equation 16 in Section 6.6.2. Pre-2014, sanctioned firms were 53% more productive at converting E&D into reserves (elasticity of 0.603 versus 0.394). Post-sanctions, productivity fell 48% for sanctioned firms (to 0.314) and 40% for non-sanctioned firms (to 0.239), likely reflecting loss of access to Western technologies and investment in less productive fields, respectively. These patterns imply that shifting investment to non-sanctioned firms resulted in substantial efficiency losses, consistent with the broader literature on sanctions and misallocation (Nigmatulina, 2023).

6 Model

I develop a dynamic model to rationalize the observed behavior of sanctioned oil companies and disentangle effects of alternative sanction mechanisms. The model describes an oil company seeking to maximize intertemporal profits across a portfolio of heterogeneous oil fields. In each field, the company makes an exploration and development (E&D) decision to unlock producible reserves, followed by optimal reserve depletion under convex costs.

I first derive optimal exploration and production under a baseline scenario with no sanction distortions. I then introduce three sanction modalities: (i) technology sanctions that act as a tax on E&D investments, (ii) financial sanctions that raise the company's cost of capital, and (iii) endogenous joint venture formation with multinational companies that attenuates channels (i) and (ii). Using this model, I simulate exploration, production, reserve depletion, abandonment timing, and government revenue generation under alternative scenarios, with company characteristics calibrated to data on sanctioned Russian oil companies' asset portfolios and sanction parameters drawn from causal event study estimates. The model is designed to capture key empirical sanction impacts documented in Section 5: a short-term increase in production, reduced exploration investment, and increased abandonment of undeveloped fields, with disproportionate impacts in technologically complex fields.

6.1 Setup

Consider a set of fields $i \in \mathcal{I}$, the oil company's asset portfolio, where each field i is characterized by geological capacity $\tilde{R}_i > 0$, representing total oil equivalent reserves, and technological complexity θ_i, proxied by the field's estimated breakeven cost at time of discovery. Time is continuous. For each field, producible reserves are denoted by $R_i(t) \geq 0$ and the extraction rate by $q_i(t) \geq 0$. A field is *undeveloped* before its development time T_i^0, with $R_i(t) = 0$ for $t < T_i^0$; *developed* on and after T_i^0 until reserves are exhausted, with $R_i(t) > 0$; and *abandoned* once reserves hit zero at some $T_i \geq T_i^0$, with $R_i(t) = 0$ for all $t \geq T_i$.

Exploration and Development (reserve creation): At development instant T_i^0, the company chooses an E&D investment level $e_i \geq 0$, which is converted into producible reserves according to $R_i(0) = G_i(e_i) \in [0, \tilde{R}_i]$, where $G_i'(e) > 0$ and $G_i''(e) \leq 0$. E&D costs are convex and increasing in technological complexity:

$$K_i(e_i, \theta_i) = \theta_i e_i^{\kappa}, \qquad \kappa > 1. \tag{1}$$

Production (reserve depletion): Following field development, the company chooses an extraction path $q_{it} \geq 0$ and reserves evolve according to $\dot{R}_i(t) = -q_i(t)$. Production ceases when $R_i(t)$ reaches zero. Production costs are convex in the extraction rate and scale with field complexity, reflecting how additional techniques and technologies can be applied to increase field-level oil production, at increasing cost:[18]

$$C_i\big(q_i(t), \theta_i\big) = \theta_i\big(q_i(t)\big)^{\phi}, \qquad \phi > 1. \tag{2}$$

Prices and discounting: The firm is assumed to be a price-taker in the global oil market, with output price $p > 0$ and government royalty rate $\gamma \in [0, 1)$ constant over time. Unless otherwise noted, payoffs are discounted at rate $r > 0$. Under an assumption that fields are operated independently, firm-level outcomes can be obtained by integrating field-level outcomes across asset portfolio $\mathcal{I}$.

Timing: With stationary primitives and no uncertainty, delaying exploration and development has no option value. Consequently, each undeveloped field either develops immediately if net present value is non-negative, or never develops.[19] Once developed, the company chooses $q_i(t)$ until depletion and then abandons the field. Because all E&D happens at time zero or not at all, the explicit timing notation T_i^0 is omitted going forward.

6.2 Baseline: Dynamic Profit Maximization

For each field in $\mathcal{I}$, the company chooses whether and how much to invest in E&D and how much to produce. The firm maximizes intertemporal profits by weighing the up-front cost of creating reserves against the discounted stream of net revenues from extraction, subject to convex costs and depletion dynamics. The resulting solution provides a benchmark against which effects of sanctions can be compared.

Already-Developed Fields: For a developed field with current reserves R_i, let $V^D(R_i, \theta_i)$ denote the current-value continuation value. The current-value Hamilton–Jacobi–Bellman

[18] In classic Hotelling models with exploration (Pindyck, 1978), firms choose exploration and production every period. Anderson et al. (2018) model well-level behavior with a one-time drilling decision followed by exogenous production decline. My field-level model adopts an intermediate approach, with firms choosing a one-time E&D investment followed by production choices under convex costs. This approach avoids the unrealistic feature that firms repeatedly explore the same field, while also relaxing the restrictive feature of fully exogenous production decline. At the field level, production can be increased through additional drilling or enhanced extraction techniques. Endogenous production is necessary to capture sanction impacts on already-developed fields.

[19] The model preserves the realistic feature that E&D occurs sequentially prior to production, and captures the core decision facing firms: whether to develop or abandon fields that were undeveloped when sanctions are imposed. Empirical results in Section 5 show exploration cuts and field abandonment began immediately following sanctions, consistent with the model's instantaneous effects. In Section 6.7, I extend the model to allow anticipation of gradual sanction decay over time.

equation is:

$$r\,V^D(R_i,\theta_i) = \max_{q_i\ge 0}\Big\{(1-\gamma)p\,q_i - \theta_i q_i^{\phi} - q_i\,V_R^D(R_i,\theta_i)\Big\}, \qquad V^D(0,\theta_i)=0, \tag{3}$$

where $V_R^D \equiv \partial V^D/\partial R$ denotes the marginal value of reserves. Define the shadow value of reserves as $\lambda_i(R) \equiv V_R^D(R,\theta_i)$, representing the opportunity cost of extracting a marginal barrel today versus preserving it for future extraction. Along the optimal path, the shadow value grows at the discount rate, $\lambda_i(t) = \lambda_{i0}\,e^{rt}$, where λ_{i0} is the initial shadow value. The first-order condition for production yields the optimal extraction path:

$$q_i^\star(t;\lambda_{i0}) = \left[\frac{(1-\gamma)p - \lambda_{i0}\,e^{rt}}{\theta_i\phi}\right]^{\frac{1}{\phi-1}}. \tag{4}$$

Production is front-loaded and declines over time as the shadow cost of reserves rises. Define $\bar{T}_i(\lambda_{i0})$ as the time at which further extraction becomes unprofitable:

$$\bar{T}_i(\lambda_{i0}) = \frac{1}{r}\log\left(\frac{(1-\gamma)p}{\lambda_{i0}}\right). \tag{5}$$

Undeveloped Fields: For an undeveloped field, the company must decide whether to invest in E&D and, if so, how much. Let $V^U(\theta_i)$ denote the option value of an undeveloped field:

$$V^U(\theta_i) = \max\left\{\sup_{e_i\ge 0}\big[V^D(G_i(e_i),\theta_i) - K_i(e_i,\theta_i)\big],\ \ 0\right\}. \tag{6}$$

If the firm chooses to develop the field, an interior solution $e_i^\star$ must satisfy the first-order condition:

$$\underbrace{V_R^D\big(G_i(e_i^\star),\theta_i\big)}_{\lambda_{i0}}\cdot\underbrace{G_i'(e_i^\star)}_{\text{marginal reserves}} = \underbrace{\frac{\partial K_i}{\partial e}(e_i^\star,\theta_i)}_{\kappa\,\theta_i\,(e_i^\star)^{\kappa-1}}, \tag{7}$$

which equates the marginal benefit of additional reserves to the marginal cost of E&D investment. Development occurs only if net present value is non-negative:

$$V^D\big(G_i(e_i^\star),\theta_i\big) - K_i(e_i^\star,\theta_i) \ge 0. \tag{8}$$

6.3 Technology Sanctions

A central component of the 2014 sanctions on Russian oil companies was a ban on provision of advanced oilfield technologies. This restriction was designed to limit the transfer of equipment and technical expertise essential for E&D in high-tech, offshore, and geologically complex fields, where Russian firms were particularly dependent on Western imports. I model these technology sanctions as an effective tax on E&D investment that scales with project complexity (proxied by baseline breakeven cost θ_i). This approach captures the idea that technology sanctions restrict access to advanced inputs, forcing firms to either pay higher prices to alternative suppliers or use inferior substitutes that increase costs through lower functionality, higher maintenance costs, or more frequent replacement.

Suppose technology sanctions raise E&D costs by a proportional wedge $\tau(\theta_i, \sigma) \geq 0$, where σ captures the severity of sanctions and τ is weakly increasing in both θ_i and σ. The production FOC for already-developed fields remains unaffected by this wedge because sanctions target e (the input into reserve creation) rather than output from reserves. Thus, technology sanctions operate exclusively through the extensive margin (fewer fields) and intensive margin (lower $R_{i,0}$) of reserve creation without distorting the dynamic extraction path conditional on development.[20] For undeveloped fields, the cost function becomes:

$$K_i(e_i, \theta_i, \sigma) = \theta_i \left[1 + \tau(\theta_i, \sigma)\right] e_i^{\kappa} \tag{9}$$

The corresponding first-order condition for E&D investment is:

$$\lambda_{i0}\, G_i'(e_i^\star) = \kappa\, \theta_i \left[1 + \tau(\theta_i, \sigma)\right] (e_i^\star)^{\kappa - 1}. \tag{10}$$

Differentiating implicitly with respect to τ gives:

$$\frac{\partial e_i^\star}{\partial \tau} = \frac{\kappa\, \theta_i\, (e_i^\star)^{\kappa-1}}{\underbrace{\lambda_{i0}\, G_i''(e_i^\star)}_{\leq 0} \;-\; \underbrace{\kappa\, \theta_i\, (\kappa - 1) \left[1 + \tau(\theta_i, \sigma)\right] (e_i^\star)^{\kappa-2}}_{>0}} \;<\; 0, \tag{11}$$

since $G_i''(e) \leq 0$ and $\kappa > 1$. Sanctions therefore reduce optimal E&D investment $e_i^\star$, and hence the reserve stock $R_{i,0} = G_i(e_i^\star)$. Under the effective sanction tax, fewer fields satisfy the development cutoff in Equation 8, and those that are developed receive less investment, leaving a larger share of total geological capacity untapped.

[20] This is built into the assumption that technology sanctions fall only on E&D, which is consistent with qualitative accounts of the policy. If production in already-developed fields also required advanced Western technologies, technology restrictions would distort the production path as well.

6.4 Financial Sanctions

The 2014 sanctions also targeted Russian oil companies' access to international financial markets, forcing them to seek funding from alternative sources at higher borrowing costs. I model this distortion as an increase in the firm-specific discount rate, which alters both E&D investment and production decisions by reducing the present value of future cash flows.

Suppose financial sanctions raise the oil company's effective discount rate by a premium $\Delta r_c(\sigma) \geq 0$, which increases in the severity of sanctions σ. The firm-specific discount rate becomes:

$$r_c^{\text{eff}} = r + \Delta r_c(\sigma), \tag{12}$$

which replaces r in the intertemporal valuation of future profits. As r_c^{eff} rises, production is increasingly front-loaded and production window $\bar{T}_i$ shortens. Furthermore, because the net present value of operating a field is strictly decreasing in r_c^{eff}, the marginal value of reserves at development, $\lambda_{i0} = V_R^D(R_i)$, falls as the discount rate rises. This implies a reduction in optimal investment $e_i^\star$, and hence a smaller reserve base $R_{i,0} = G_i(e_i^\star)$. Financial sanctions thus distort the dynamic reserve depletion path by shifting production forward in time, and reserve creation by discouraging development of marginal fields. This mechanism generates the short-termist production response observed in event studies of the 2014 sanctions.

The financial sanctions channel has a more general interpretation. If the government requires short-term revenues (for instance, to finance military operations that triggered sanctions in the first place) it may pressure state-affiliated firms to prioritize current production over long-term investment. From the firm's perspective, this is equivalent to a financial sanction: both represent an externally imposed increase in the effective discount rate. The estimated financial sanctions wedge should therefore be interpreted as the combined effect of capital market restrictions and any political pressure firms may have felt for short-term revenue generation.[21]

[21] Rosneft and Gazprom board meeting transcripts from S&P Global Market Intelligence (2024) and contemporaneous reporting do not describe government pressure to prioritize current production. On the other hand, Appendix Figure A15 shows spikes in Russian military expenditure after 2014 and 2022, which could create fiscal pressure on the government to increase oil revenues.

6.5 Multinational Participation

After the 2014 sanctions, existing partnerships between Russian oil companies and MNCs were allowed to continue under grandfathering provisions. This may have attenuated the effect of sanctions in joint ventures, as MNCs continued to provide access to technologies and financing that would otherwise have been restricted. I model MNC participation as an endogenous decision: MNCs weigh the value of staying in a project under sanctions against costs of compliance and reputational risk. When MNCs remain, they mitigate both technology and finance wedges. When they exit, the sanctioned company bears the full burden of sanctions.

Let $M_i \in \{0, 1\}$ indicate whether an MNC partner remains involved in field i ($M_i = 1$ if present) and $m \in [0, 1]$ be the degree to which MNCs reduce sanction wedges. With an MNC partner ($M_i = 1$), both wedges are attenuated multiplicatively:

$$\tau_i^{\text{eff}}(\theta_i, \sigma, M_i) = \tau(\theta_i, \sigma) \cdot (1 - mM_i), \tag{13}$$

$$r_{c,i}^{\text{eff}}(\sigma, M_i) = r + \Delta r_c(\sigma) \cdot (1 - mM_i). \tag{14}$$

In the absence of an MNC partner ($M_i = 0$), the operator faces full sanction wedges. Timing is as follows: (1) at $t = 0$, the sanction regime σ and field primitives $(\theta_i, \tilde{R}_i)$ are observed; (2) the MNC chooses whether to stay or exit, anticipating the operator's optimal behavior; (3) conditional on M_i, the domestic operator decides whether to develop the field ($e_i \geq 0$), and if developed, optimal extraction follows.

Let $\mathcal{V}_i^{\text{stay}}(\sigma)$ and $\mathcal{V}_i^{\text{exit}}(\sigma)$ denote the net present value of field i when the MNC stays or exits, respectively, where each equals continuation value V^D evaluated at the optimal reserve level $G_i(e_i^\star)$ minus the E&D cost, with effective wedges τ_i^{eff} and $r_{c,i}^{\text{eff}}$ determined by M_i. Let α_i be the MNC's equity share in field i and $\bar{\Pi}(\sigma)$ be an exit threshold increasing in sanction severity. The MNC stays if:

$$\alpha_i \, \mathcal{V}_i^{\text{stay}}(\sigma) \; \geq \; \bar{\Pi}(\sigma), \tag{15}$$

6.6 Model Calibration and Simulation

6.6.1 Illustrative Single Field Simulation

To illustrate the model's core mechanisms and predictions, I begin with a single-field simulation of a representative oil field under alternative sanction scenarios. The field is calibrated to reflect a generic conventional oil project, with parameter values reported and described in Appendix B11. I simulate five scenarios that isolate the effects of different sanction mechanisms:

1. **Baseline** ($\tau = 0$, $\Delta r_c = 0$)
2. **Technology Sanctions** ($\tau = 0.60$, $\Delta r_c = 0$, MNC present)
3. **Financial Sanctions** ($\tau = 0$, $\Delta r_c = 0.15$, MNC present)
4. **Tech & Financial** ($\tau = 0.60$, $\Delta r_c = 0.15$, MNC present)
5. **Tech & Financial with MNC Exit** ($\tau = 0.60$, $\Delta r_c = 0.15$, MNC absent)

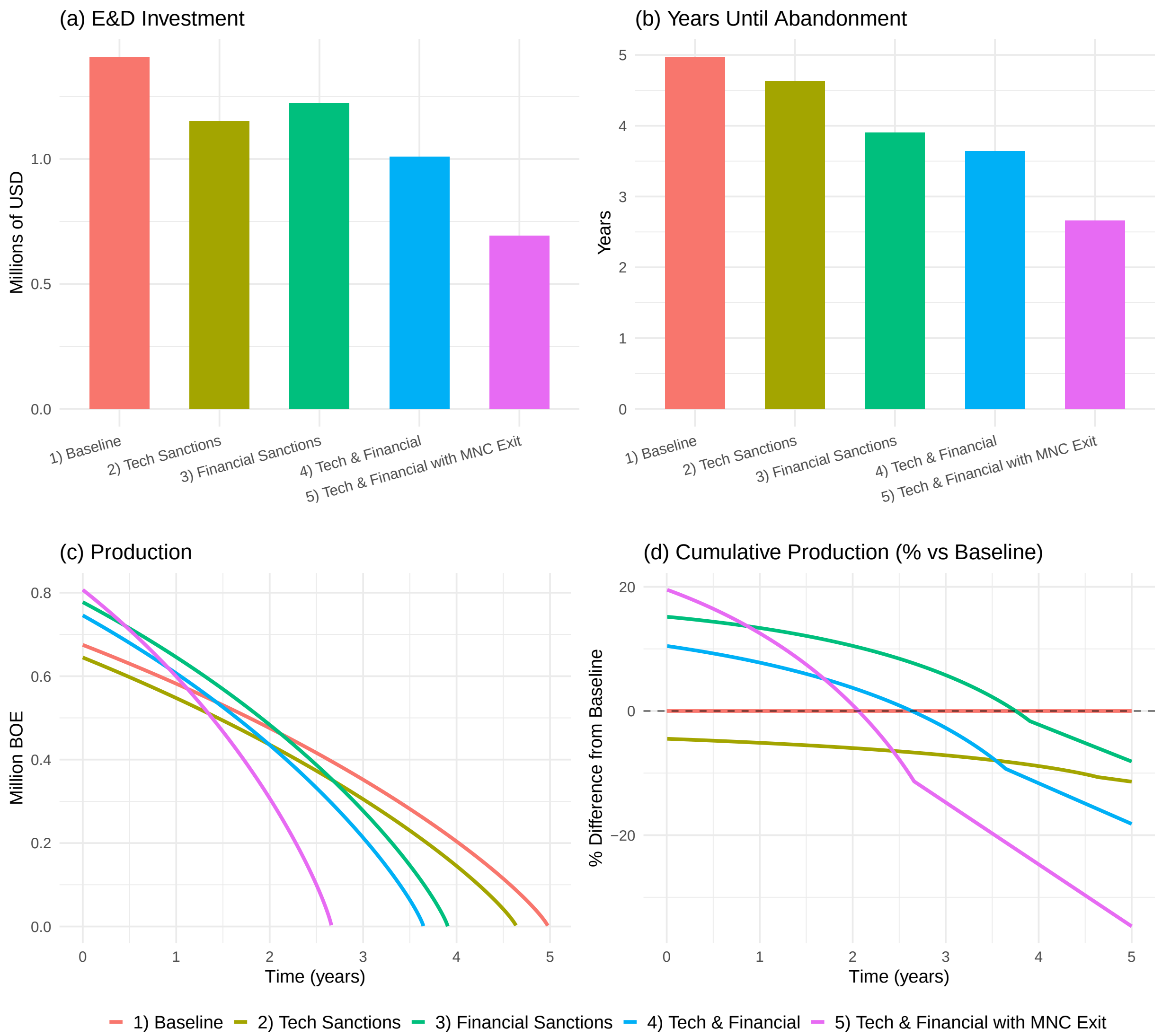
In scenarios 2–4, MNC partnerships attenuate both wedges according to Equations (13)–(14). Scenario 4 is the empirical analog, given both technology and financial sanctions were imposed on targeted Russian oil companies after 2014, but MNCs were not required to exit from joint ventures. Scenario 5 represents a counterfactual policy mandating MNC exit.[22]

Results from this single-field simulation are presented in Figure 7. Panel (a) shows instantaneous E&D investment, (b) shows field abandonment timing, (c) shows current production, and (d) shows the percentage difference in cumulative production between sanction scenarios and the baseline scenario. All sanction scenarios reduce E&D investment and accelerate field abandonment relative to the dynamic optimum, with combined sanction distortions exhibiting cumulative impacts. Scenario 4, which combines technology sanctions and financial sanctions (the empirical analog) reproduces the key empirical patterns documented in Section 5: reduced exploration investment, accelerated field abandonment, and short-term

[22]For each scenario, I solve the field's dynamic optimization problem using a shooting algorithm. The initial shadow value of reserves λ_{i0} must satisfy a consistency condition wherein cumulative extraction over the field's lifetime must equal total reserves created through E&D investment. The algorithm iterates as follows: for a candidate λ_{i0}, compute optimal E&D investment $e_i^\star$, calculate initial reserves $R_{i,0} = G_i(e_i^\star)$, numerically integrate the production path until production ceases, and adjust λ_{i0} using root-finding until the consistency condition is satisfied. Fields are developed only if net present value is non-negative. Time is discretized with step size $\Delta t = 0.005$.

production growth. Alternative scenarios disentangle sanction mechanisms. Technology sanctions (2) shift production downward in every period due to lower initial reserves, but do not distort production intertemporally. In contrast, financial sanctions (3) shift production forward in time by devaluing future extraction. MNC exit (5) exacerbates both distortions.

Figure 7: Illustrative Single Field Simulations



Note: Figure shows simulated E&D investment, abandonment timing, and current and cumulative production for a single illustrative oil field. Baseline parameters are set to generic values. The net oil price is $p = 75$ (USD/bbl) with an ad valorem royalty rate of $\gamma = 0.30$. Operating costs follow $C(q) = \theta q^{\phi}$ with $\theta = 15$ and $\phi = 2.2$. The discount rate is $r = 0.10$. The reserve–creation function is $G(e) = Ae^{\beta}$ with $A = 1.6$ and $\beta = 0.6$. Exploration and development costs are $K(e;\theta,\tau^x) = \theta(1+\tau^x)e^{\kappa}$ with $\kappa = 1.6$. Initial producible reserves are $R_0 = 0$, with no geological cap ($R^{\text{cap}} = \infty$). Sanction scenarios vary two wedges: (i) a technology sanction wedge $\tau^x = 0.60$ (attenuated by multinational participation $m_{\text{att}} = 0.60$ and scaled by θ), and (ii) a financial sanction premium $\Delta r_c = 0.15$, applied additively to discount rate r.

6.6.2 Portfolio-Level Simulation and Calibration

I next calibrate the model to generate realistic predictions and counterfactual estimates for a portfolio of fields matching the empirical portfolio operated by sanctioned Russian oil companies as of 2013.

Moment Matching: I compute empirical moments from the sample of sanctioned Russian oil fields in 2013: the mean and standard deviation of field complexity θ_i (proxied by baseline breakeven costs) and geological capacity $\tilde{R}_i$ (original oil in place), the share of fields already developed, and share of fields with MNC joint ventures. I then create 400 synthetic fields by sampling from lognormal and Bernoulli distributions calibrated to match the empirical moments of continuous and binary variables, respectively. Empirical and simulated moments are reported in Appendix Table B12.

Structural Parameter Estimation: The model's reserve creation function and production cost functions are governed by structural parameters that can be estimated from field-level data. The reserve creation function $G(e) = Ae^{\beta}$ determines how E&D investment translates into producible reserves. To calibrate β and A, I regress the log of peak reserves in field i, R_i^{peak} (maximum technical reserves, observed at time T_i), on the log of cumulative exploration and capital expenditure, controlling for baseline breakeven cost, original oil in place, well depth, discovery year, and oblast:

$$\ln(R_i^{\text{peak}}) = \ln A + \beta \cdot \ln\left(\sum_{t=t_0}^{T_i} e_{it}\right) + \mathbf{X}_i'\gamma + \varepsilon_i \tag{16}$$

Estimating this specification separately for sanctioned and non-sanctioned fields using pre-2014 data yields $\hat{\beta}_s = 0.603$ (SE $= 0.025$) and $\hat{A}_s = 2.04$ for sanctioned firms, compared to $\hat{\beta}_{ns} = 0.394$ (SE $= 0.029$) and $\hat{A}_{ns} = 1.20$ for non-sanctioned firms (Appendix Table B13). These estimates indicate moderate diminishing returns to E&D investment: for sanctioned firms, a 10% increase in cumulative E&D generates an approximately 6% increase in reserves.

To estimate ϕ in the production cost function $C(q, \theta) = \theta q^{\phi}$, I follow Bornstein et al. (2023) and regress log operating costs per barrel of reserves R in field i in year t on log extraction rates, with field fixed effects. To address endogeneity between extraction and operating costs, I instrument extraction rates with the global Brent crude oil price, which shifts extraction but is exogenous to field-specific costs:

$$\ln\left(\frac{\text{Opex}_{it}}{R_{it}}\right) = \phi \ln\left(\frac{\widehat{q_{it}}}{R_{it}}\right) + \alpha_i + \varepsilon_{it} \tag{17}$$

I use pre-sanction data (2000-2013) from Russian fields with positive production operated by companies that were sanctioned in 2014. This estimation yields $\hat{\phi} = 3.02$ (SE $= 0.115$, first-stage F-stat $= 372$), confirming convex production costs and implying that a 10% increase in the extraction rate raises operating costs by 30%. Estimation results are reported in Appendix Table B14.[23]

Sanction Intensity Calibration: I calibrate sanction wedges τ^x (technology) and Δr_c (financial) by matching model predictions for Scenario 4 (tech + financial sanctions with no MNC exit) to reduced-form event study estimates. Main event study results indicate that sanctions increased short-run production by 2.8% and reduced E&D investment by 15% in sanctioned fields. I find that $\tau^x = 0.14$ and $\Delta r_c = 0.037$ generate impacts that closely match these magnitudes.

The MNC attenuation parameter m determines how joint ventures with multinational companies reduce technology and financial sanction wedges. To estimate m, I exploit continuous variation in MNC partnership shares across fields pre- and post-sanctions using a difference-in-differences specification:

$$y_{it} = \beta_1 \text{MNC\%}_{it} + \beta_2 \text{Post}_t + \beta_3 (\text{MNC\%} \times \text{Post})_{it} + \alpha_i + \varepsilon_{it} \tag{18}$$

where y_{it} represents outcomes in field i and year t, $\text{MNC\%}_{it}$ is the MNC equity share, Post_t is an indicator for years after 2013, and α_i are field fixed effects. The interaction coefficient β_3 measures how much an additional p.p. of MNC ownership moderates sanction impacts. Results (see Appendix Table B15) show that, at the mean post-sanction MNC equity share of 12.5%, MNC presence preserves 1.9% more production and 1.5% more exploration investment, and reduces field inactivity probability by 6 p.p relative to fields with no MNC

[23] Estimating κ from the E&D cost function $K(e, \theta) = \theta e^{\kappa}$ using observational data is difficult because (i) I observe optimal E&D spending, which reflects both the cost function and the firm's shadow value of reserves, and (ii) κ is identified only jointly with the reserve creation parameters (A, β) and the shadow value, creating a simultaneity problem. Given these identification challenges, I calibrate $\kappa = 1.6$ following petroleum engineering estimates.

partner. I calibrate $m = 0.35$ to approximate these impact magnitudes, measured as the difference in production, exploration, and abandonment timing between Scenario 4 (tech + financial sanctions with no MNC exit) and 5 (tech + financial sanctions with MNC exit). Appendix Table B16 summarizes all calibrated parameters, and Appendix Table B17 reports empirical sanction impacts from event studies compared to modeled impacts.

6.7 Model Results

Calibrated model results are reported in Appendix Figure A16 and Appendix Table B18. Estimates suggest that technology and financial sanctions imposed on Russia in 2014 (analogous to Scenario 4) will accelerate the average timing of field abandonment by 3.7 years, or 18.4% (from 20.3 to 16.6 years), and impose a cumulative loss in Russian government oil revenues of US$32.5 billion, or 3.4% (from US$971.4 billion to US$938.8 billion) over 20 years. E&D investment is estimated to fall by 22.2%.

Under a counterfactual policy of technology sanctions alone (Scenario 2), field abandonment is estimated to accelerate by 0.1 years, or 0.3% relative to baseline, and cumulative government oil revenues are estimated to decline by US$3.5 billion, or 0.4% over 20 years. Under financial sanctions alone (Scenario 3), field abandonment is estimated to accelerate by 3.7 years, or 18.2% relative to baseline, and cumulative government oil revenues are estimated to decline by US$29.6 billion, or 3.0% over 20 years, accounting for the bulk of the combined effect in Scenario 4. The joint pattern of production increase and exploration decline provides model-based identification: because technology sanctions operate exclusively through reserve creation without distorting the extraction path of already-developed fields, only the financial channel can generate both margins simultaneously. Technology sanctions affect the magnitude of exploration cuts, but cannot on their own generate short-termism.

If, on top of technology and financial sanctions, MNCs had been prohibited from participating in Russian joint ventures after 2014 (Scenario 5), model estimates suggest that average field abandonment would accelerate by an additional 0.1 years and government oil revenues would decline by a further US$1.6 billion, or 0.1% over 20 years. At the same time, exclusion of MNCs would have imposed substantial costs on multinationals themselves (i.e., "friendly fire"), reducing their cumulative discounted profits by roughly US$63 billion over the same horizon.[24] This large loss for comparatively small gain may help explain why this additional restriction was not imposed in 2014. When MNCs did exit *en masse* after 2022, they absorbed significant losses from the abandonment of fixed capital and forfeiture of equity positions in joint ventures.

Extension 1: Sanction Decay To test how sanction impacts change if targeted firms gradually locate alternative sources of technology and financing over time, I allow technology sanction wedge τ^x to decay linearly to zero over 20 years, while the financial sanction wedge Δr_c decays linearly by half, reflecting that alternative technology suppliers or domestic substitutes may be easier to source than alternative lenders. Appendix Table B19 and Figure A17 report results. With sanction decay, cumulative production losses relative to baseline shrink from 3.4% to 1.2% and government revenue losses fall from \$32.5 billion to \$11.4 billion over 20 years.[25]

Extension 2: Output Price Cap The 2022 G7 price cap on Russian oil provides a potential alternative or complement to input sanctions. I simulate joint impacts of input sanctions and a \$60/barrel price ceiling, representing a 23% reduction from the baseline \$78/barrel. Appendix Table B20 and Figure A18 report results. The price cap alone reduces E&D investment by 36%, cumulative production by 8.6%, and government revenues by 30% over 20 years. The price cap in conjunction with input sanctions reduces E&D investment by 50% and government revenues by 32% – driven by both reduced production (-12%) and reduced revenues on remaining output. The price cap directly reduces revenues per barrel while input sanctions constrain long-run capacity, making their combination particularly impactful.

[24] This value is calculated as the product of MNCs' equity share in sanctioned joint ventures and annual after-tax profits after 2013. Per-barrel profits are approximated as the difference between the 2013 Brent Crude oil price (US\$78) and the average breakeven price in sanctioned fields (US\$62), yielding a pre-tax margin of US\$16 per barrel. Applying the prevailing corporate tax rate of 16.44% yields an after-tax margin of US\$13.37 per barrel. Annual after-tax profits are computed by multiplying this margin by total production under Scenario 4 and discounted over a 20-year horizon using the Russian risk-free rate of 7.33%.

[25] This scenario assumes perfect foresight over rates of sanction decay. Anticipating lower technology sanctions in future periods, firms could potentially delay E&D investments. Under the model's calibration, however, the technology sanction wedge is too small relative to discounting to generate strategic delays in E&D, resulting in identical reserve creation in the first period.

Model Limitations: I make several simplifications for tractability. First, the model isolates effects of the 2014 sanctions and does not account for further distortions introduced after 2022. Second, it abstracts from oil price volatility and uncertainty, which could influence both exploration timing and production strategies. Third, the model assumes field separability, which is supported by the independence of reservoir dynamics across fields. Finally, the model assumes that sanctions stay in place forever once imposed, and that firms anticipate this. In practice, expectations of future tightening or easing of sanctions could generate richer dynamic responses. Relaxing these simplifying assumptions represents an avenue for future research.

7 Conclusion

Sanctions have become one of the most far-reaching tools of international policy, offering an option for deterrence between diplomacy and war. Nevertheless, when targeted at large, complex firms, sanctions can produce unintended or delayed effects that are not immediately visible, given the multiple margins of adjustment available to these organizations. I show that sanctions imposed on Russian oil companies in 2014 induced short-termism, prompting firms to increase current oil production while sharply reducing exploration and development of new fields. Sanctioned firms also became increasingly isolated as multinational partners withdrew from joint ventures, and reallocation of exploration capital toward less productive non-sanctioned firms likely generated aggregate efficiency losses.

Using a dynamic model of oil company decision-making, I rationalize these effects as the joint result of two mechanisms: technology sanctions, which act as a tax on exploration and development, and financial sanctions, which raise the firm's cost of capital, prompting it to discount future returns more heavily and shift production forward in time. Simulations calibrated to Russian oil fields indicate that combined effects of these 2014 sanctions will lead to substantially lower reserve creation, accelerated field abandonment, and reduced cumulative production and government revenues over a 20-year horizon.

The central tension revealed by this analysis is a mismatch between the time horizon over which input sanctions inflict damage and the time horizon over which they are intended to influence or coerce policymakers. Although many observers initially viewed the 2014 sanctions as ineffective because they did not cause an immediate drop in Russian oil output, my findings show these policies eroded future productive capacity. This was consistent with stated policy objectives, but on a timeline of 10-20 years rather than months. Moreover, because sanctions coincided with invasions of Ukraine, sanction-induced short-termism may have inadvertently increased Russian oil revenues precisely when fiscal capacity was needed to finance conflict.

This perverse effect reflects a deeper constraint on sanction design: the more severe the sanctions, the higher the target's effective discount rate, and therefore the less future costs weigh on current decisions. At the limit, an organization facing existential pressure discounts the future almost entirely, and the coercive mechanism breaks down. In sum, input sanctions may degrade future capacity without changing current behavior if short-termism prevails.

References

Abadie, A., S. Athey, G. W. Imbens, and J. M. Wooldridge (2022). When Should You Adjust Standard Errors for Clustering? *The Quarterly Journal of Economics 138*(1), 1–35.

Afesorgbor, S. (2019). The Impact of Economic Sanctions on International Trade: How do Threatened Sanctions Compare with Imposed Sanctions? *European Journal of Political Economy 56*, 11–26.

Ahlvik, L., J. J. Andersen, J. H. Hamang, and T. Harding (2024). Quantifying Supply-Side Climate Policies. Review of Economic Studies (conditionally accepted).

Ahn, D. and R. D. Ludema (2020). The Sword and the Shield: The Economics of Targeted Sanctions. *European Economic Review 130*.

Altiparmak, S. O., C. G. Thies, S. T. Shutters, and K. Waters (2023, March–April). Inducing New Bilateral Oil Interdependencies: The Unintended Impact of 2014 US-led Sanctions on Russia. *Journal of Indo-Pacific Affairs 6*(3), 154–165.

Anderson, S., R. Kellogg, and S. Salant (2018). Hotelling under Pressure. *Journal of Political Economy 126*(3).

Arbatli, C. E. and D. Gomtsyan (2021). Sectarian Aid, Sanctions and Subnational Development. *European Economic Review 139*, 103891.

Baker, P., A. Cowell, and J. Kanter (2014). Coordinated sanctions aim at russia's ability to tap its oil reserves. Technical report, The New York Times.

Bellemare, M. F. and C. J. Wichman (2019). Elasticities and the Inverse Hyperbolic Sine Transformation. *Oxford Bulletin of Economics and Statistics 82*(1), 50–61.

Berman, N. (2024). Two Years Into the War in Ukraine, Are Sanctions Against Russia Making a Difference? Accessed: 2025-04-28.

Bianchi, J. and C. Sosa-Padilla (2023). The Macroeconomic Consequences of International Financial Sanctions. *AEA Papers and Proceedings 113*, 29–32.

Bornstein, G., P. Krusell, and S. Rebelo (2023). A World Equilibrium Model of the Oil Market. *The Review of Economic Studies 90*(1), 132–164.

Callaway, B. and P. H. C. Sant'Anna (2021). Difference-in-Differences with Multiple Time Periods. *Journal of Econometrics 225*(2), 200–230.

Cardoso, D., J. Daubanes, and S. Salant (2025). The Dynamics of Evasion: The Price Cap on Russian Oil Exports and the Amassing of the Shadow Fleet. CESifo Working Paper 11618, CESifo. Accessed: 2025-04-28.

Chen, J., M. Gao, S. Cheng, W. Hou, M. Song, X. Liu, and Y. Liu (2022). Global 1 km × 1 km Gridded Revised Real Gross Domestic Product and Electricity Consumption During 1992–2019 Based on Calibrated Nighttime Light Data. *Scientific Data 9*(1), 202.

Chen, J. and J. Roth (2023). Logs with Zeros? Some Problems and Solutions. *The Quarterly Journal of Economics 139*(2), 891–936.

Coote, B. (2017). The Impact of Sanctions on Russia's Energy Sector. Technical report, Atlantic Council. Accessed: 2025-04-28.

Coulomb, R., F. Henriet, and L. Reitzmann (2025). 'Bad' Oil, 'Worse' Oil, and Carbon Misallocation. *Review of Economic Studies (forthcoming)*.

Crozet, M. and J. Hinz (2020). Friendly Fire: the Trade Impact of the Russia Sanctions and Counter-Sanctions. *Economic Policy 35*(101), 97–146.

Dai, M., G. Felbermayr, A. Kirilakha, C. Syropoulos, E. Yalcin, and Y. Yotov (2021). Timing the Impact of Sanctions on Trade. School of Economics Working Paper Series 2021-7, LeBow College of Business, Drexel University.

EIA (2023). Country Analysis Brief: Libya. Technical report, U.S. Energy Information Administration.

Farzanegan, M. R. (2011). Oil revenue shocks and government spending behavior in Iran. *Energy Economics 33*(6), 1055–1069.

Felbermayr, G., A. Kirilakha, C. Syropoulos, E. Yalcin, and Y. V. Yotov (2020). The Global Sanctions Data Base. *European Economic Review 129*.

Felbermayr, G., T. C. Morgan, C. Syropoulos, and Y. V. Yotov (2024). Economic Sanctions: Stylized Facts and Quantitative Evidence. Technical Report 2024001, CESifo.

Giroud, X. and H. M. Mueller (2019, October). Firms' Internal Networks and Local Economic Shocks. *American Economic Review 109*(10), 3617–49.

Gross, S. and C. Stelzenmüller (2024). Europe's messy Russian Gas Divorce. Technical report, Brookings Institution.

Haidar, J. I. (2017). Sanctions and Export Deflection: Evidence from Iran. *Economic Policy 32*(90), 319–355.

Hotelling, H. (1931). The Economics of Exhaustible Resources. *Journal of Political Economy 39*(2), 137–175.

Iacus, S. M., G. King, and G. Porro (2012). Causal Inference Without Balance Checking: Coarsened Exact Matching. *Political Analysis 20*(1), 1–24.

Itskhoki, O. and D. Mukhin (2025, 09). Sanctions and the Exchange Rate. *The Review of Economic Studies*, rdaf085.

Johnson, S., L. Rachel, and C. Wolfram (2023). Design and implementation of the price cap on Russian oil exports. *Journal of Comparative Economics 51*(4), 1244–1252.

Johnson, S. and C. Wolfram (2024). Strengthening Enforcement of the Russian Oil Price Cap. Policy brief, Brookings Institution. Accessed: 2025-04-28.

Kellogg, R. (2011). Learning by Drilling: Interfirm Learning and Relationship Persistence in the Texas Oilpatch. *The Quarterly Journal of Economics 126*(4), 1961–2004.

Kilian, L., D. Rapson, and B. Schipper (2025, January). The Impact of the 2022 Oil Embargo and Price Cap on Russian Oil Prices. Working Paper 2401, Federal Reserve Bank of Dallas, Research Department. Revised January 2025.

Korovkin, V. and A. Makarin (2023, January). Conflict and Intergroup Trade: Evidence from the 2014 Russia-Ukraine Crisis. *American Economic Review 113*(1), 34–70.

Kwon, O. (2023). Do Sanctions Affect Growth? Technical Report 9818, CESifo Working Paper.

Lee, Y. S. (2014). Countering Sanctions: The Unequal Geographic Impact of Economic Sanctions in North Korea. Working Paper 519, Stanford Center for International Development.

Lorenzoni, G. and I. Werning (2023). A Minimalist Model for the Ruble During the Russian Invasion of Ukraine. *American Economic Review: Insights 5*(3), 347–356.

MacKinnon, J. G. and M. D. Webb (2018). The Wild Bootstrap for Few (Treated) Clusters. *The Econometrics Journal 21*(2), 114–135.

Maksimovic, V. and G. Phillips (2002). Do Conglomerate Firms Allocate Resources Inefficiently Across Industries? Theory and Evidence. *Journal of Finance 57*(2), 721–767.

Mamonov, M., A. Pestova, and S. Ongena (2021). Crime and Punishment?: How Russian Banks Anticipated and Dealt with Global Financial Sanctions. Technical report, Centre for Economic Policy Research.

Mathiasen, K. and N. Martinez (2019). Barreling Blindly Ahead: The Seizure of Venezuela's Oil. Center for Global Development. Accessed: February 19, 2026.

Milov, V. (2024). Oil, Gas, and War: The Effect of Sanctions on the Russian Energy Industry. Technical report, Atlantic Council. Accessed: 2025-07-31.

Mäe, A. (2016). How Have Sanctions Affected the Russian Oil Sector? International Center for Defense and Security. Accessed: 2025-07-29.

Nguyen, T. T. and M. H. Do (2021). Impact of Economic Sanctions and Counter-Sanctions on the Russian Federation's Trade. *Economic Analysis and Policy 71* (C), 267–278.

Nigmatulina, D. (2023). Sanctions and Misallocation: How Sanctioned Firms Won and Russians Lost. Working Paper.

Oechslin, M. (2014). Targeting Autocrats: Economic Sanctions and Regime Change. *European Journal of Political Economy 36*, 24–40.

OpenSanctions (2025). Sanctions Dataset. https://www.opensanctions.org/datasets/sanctions/. Accessed: 2025-04-28.

Panin, A. (2014). China Beating Russian Firms in Drive to Replace Sanctioned Western Technology. The Moscow Times. Accessed: 2025-07-29.

Payne Institute for Public Policy (2024). VIIRS Nightfire Global Gas Flare Data. https://eogdata.mines.edu/products/vnf/global_gas_flare.html. Accessed: 2024-04-28.

Peksen, D. and A. C. Drury (2010). Coercive or Corrosive: The Negative Impact of Economic Sanctions on Democracy. *International Interactions 36* (3), 240–264.

Pindyck, R. (1978). The Optimal Exploration and Production of Nonrenewable Resources. *Journal of Political Economy 86* (5).

Reuters (2022). Western Companies in Russia's Oil and Gas Sector. Technical report, Reuters.

Rodríguez, F. (2023). The Human Consequences of Economic Sanctions. Technical report, CEPR.

Rybakova, T. (2025). All Work and Low Pay: Inside Russia's Labor-Starved Military Economy. Technical report, The Insider.

Rystad Energy (2025). U-Cube Upstream Solution. https://www.rystadenergy.com/services/upstream-solution. Accessed: 2025-05-04.

Sanusi, A. R., S. O. Mamman, J. Iliyasu, and A. B. Abubakar (2023). Financial Sanctions and the Share of US dollar in Global Reserve Currencies: Evidence from the Least Absolute Shrinkage and Selection Operator (LASSO) Model. *Applied Economics Letters*. Forthcoming.

Sharma, G. (2024). What Sanctions? 85% of Russia's Oil Finds Buyers in China and India. *Forbes*. Accessed: 2025-04-28.

Shingal, A. (2024). Economic Sanctions and Domestic Diversion. *Economics Letters 244* (C).

Shrivastava, M. (2024). How Is Huawei Growing, Despite Heavy US Sanctions? The Diplomat. Retrieved from https://thediplomat.com/2024/07/how-is-huawei-growing-despite-heavy-us-sanctions/.

Siegle, C. Pressure at the Pump: Ukraine Resumes Strikes on Russian Oil Refineries, institution = Center for Strategic and International Studies, year = 2025, url = https://www.csis.org/analysis/pressure-pump-ukraine-resumes-strikes-russian-oil-refineries. Technical report.

S&P Global Market Intelligence (2024). S&P Capital IQ Pro. https://www.capitaliq.com. Accessed: 2024-04-28.

Spiro, D., H. Wachtmeister, and J. Gars (2024). Assessing the Impact of Oil Sanctions on Russia. SSRN Electronic Journal. Available at SSRN: https://ssrn.com/abstract=5071223 or http://dx.doi.org/10.2139/ssrn.5071223.

Stockholm International Peace Research Institute (2025). SIPRI Military Expenditure Database. https://www.sipri.org/databases/milex. Accessed: October 19, 2025.

U.S. Department of the Treasury (2014). Announcement of Expanded Treasury Sanctions within the Russian Financial Services, Energy and Defense or Related Materiel Sectors. https://home.treasury.gov/news/press-releases/jl2629. Accessed: 2024-04-28.

U.S. Department of the Treasury (2024). Sanctions Programs and Information FAQs. Accessed April 28, 2025.

U.S. Office of Foreign Assets Control (2024). Consolidated sanctions list. https://sanctionslist.ofac.treas.gov/Home/ConsolidatedList. Accessed: 2024-04-28.

World Bank (2024). World Development Indicators. https://databank.worldbank.org/source/world-development-indicators. Accessed: 2025-04-28.

Yermakov, V. (2024). Follow the Money: Russian Oil and Gas Revenues. OIES Paper, Oxford Institute for Energy Studies.

Online Appendix

Slaying Giants? Dynamic Impacts of Sanctions on Oil Companies

Erik Katovich

April 3, 2026

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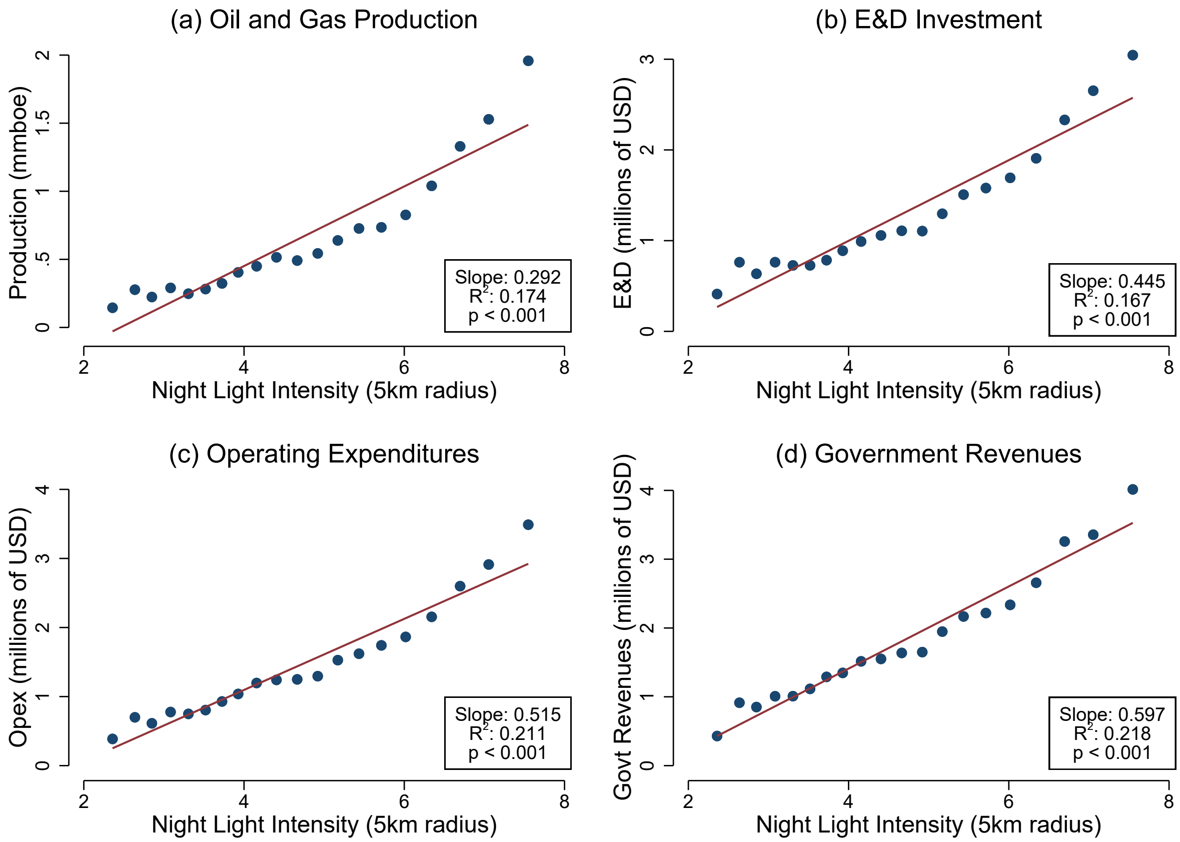
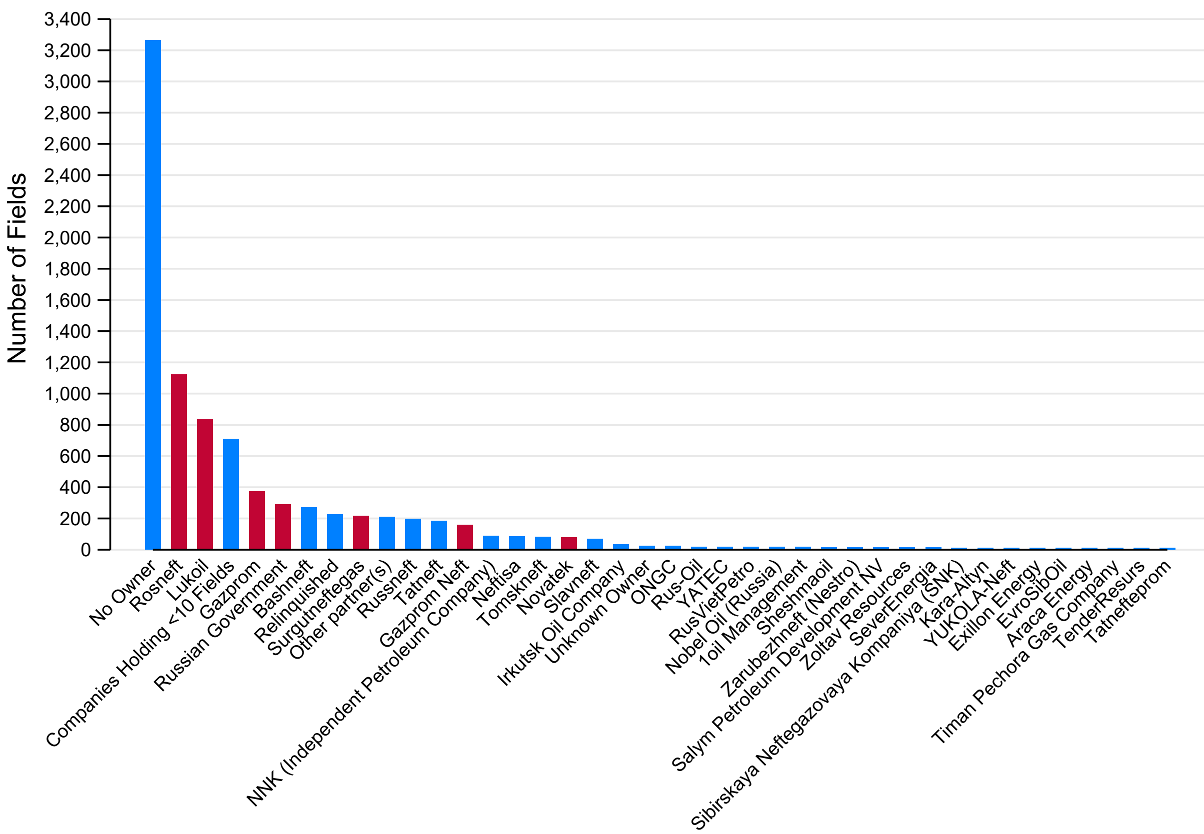
A Supplementary Figures

Figure A1: Correlations between Rystad Data and Night Light Intensity



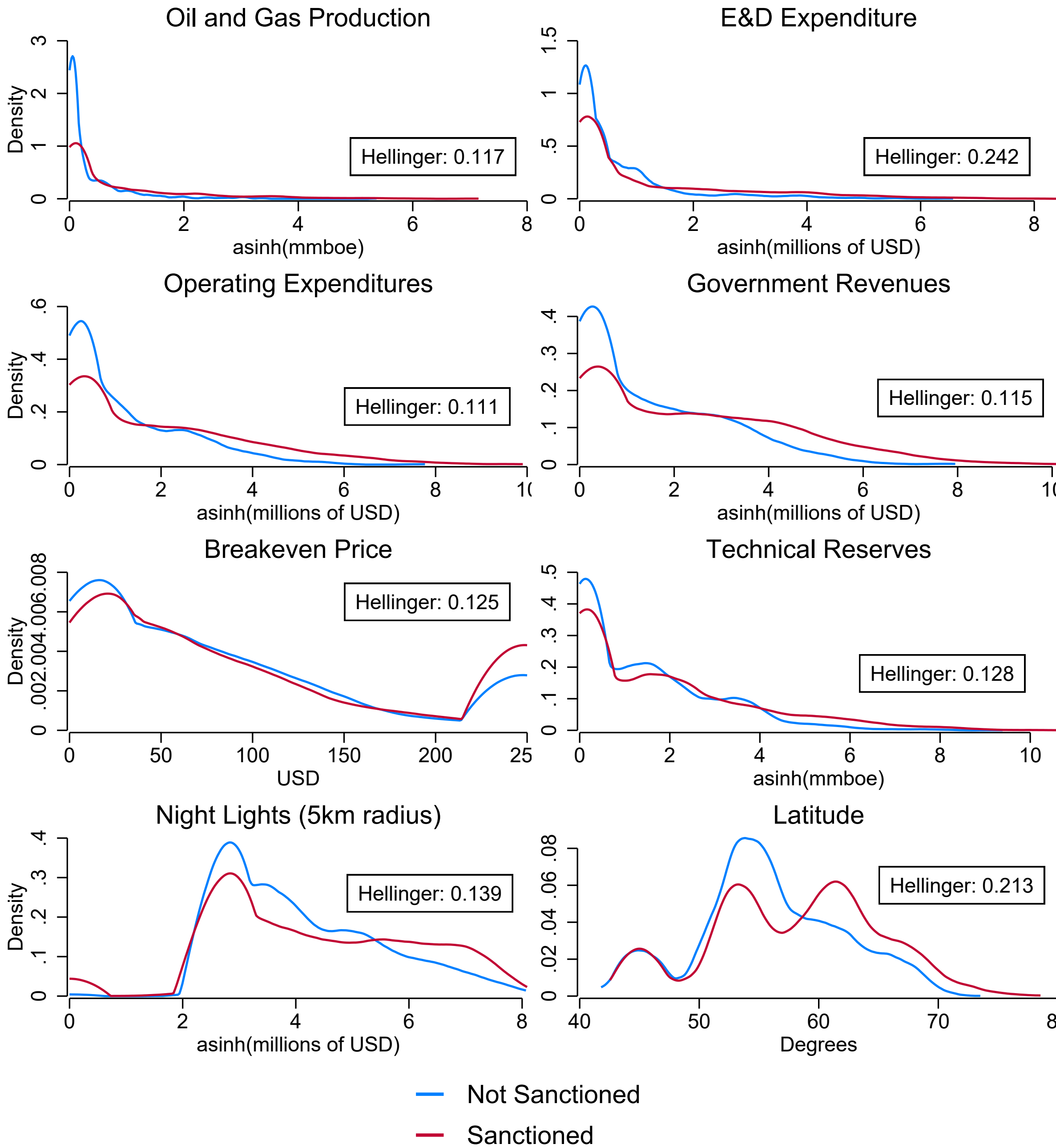
Note: Binned scatterplots report correlations between night lights intensity within 5km of oil field centroids and (a) oil and gas production, in millions of barrels of oil equivalent, (b) exploration and capital expenditures, in millions of USD, (c) operating expenditures, in millions of USD, and (d) government revenues from taxes and royalties, in millions of USD. All outcomes are transformed using the inverse hyperbolic sine function. The sample is restricted to active Russian oil and gas fields with non-zero production between 2000-2024, excluding offshore fields – where night lights are not reliably measured. Night lights data are from Chen et al. (2022).

Figure A2: Field Ownership by Company in 2013



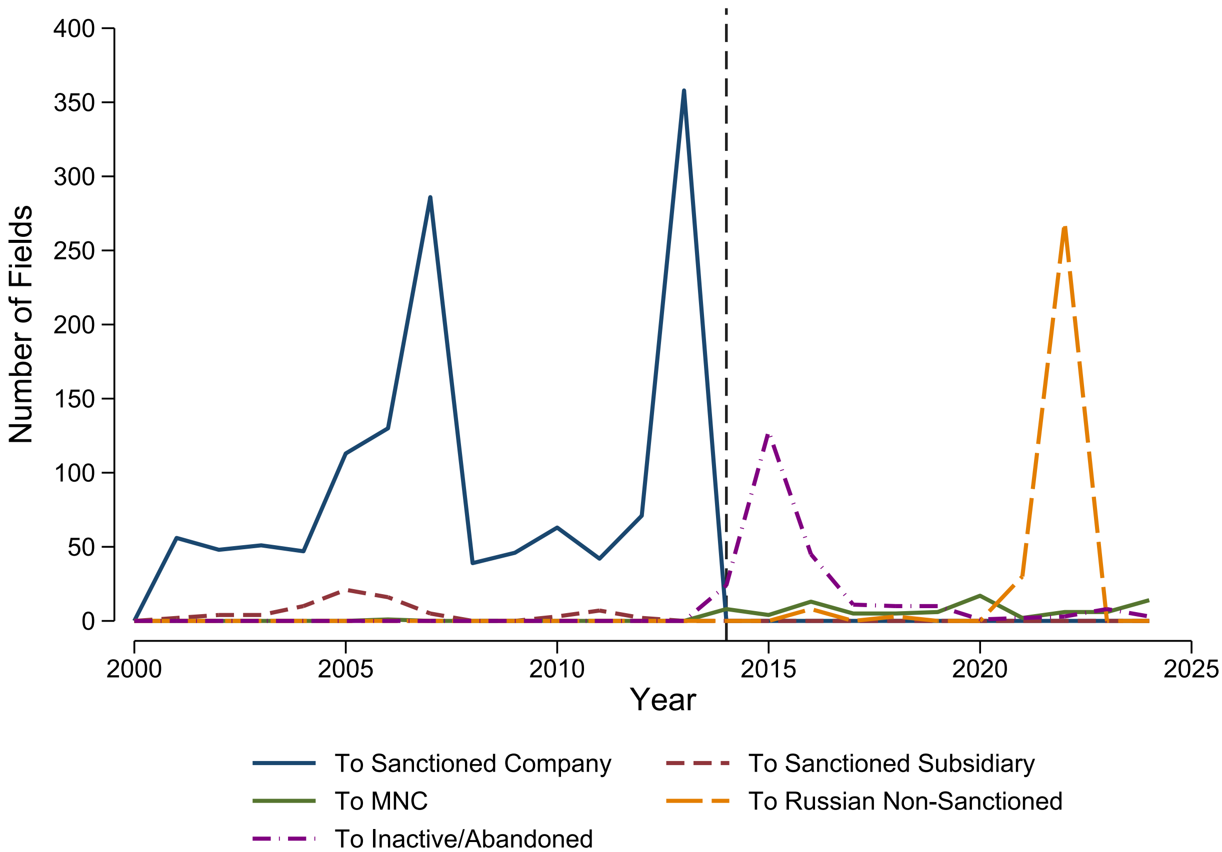
Note: Red bars indicate organizations that were sanctioned in 2014. Blue bars indicate non-sanctioned organizations. Fields with no registered owner are inactive as of 2013, but may be operated by a company at some other point between 2000-2024.

Figure A3: Comparing Distributions between Sanctioned and Non-Sanctioned Fields



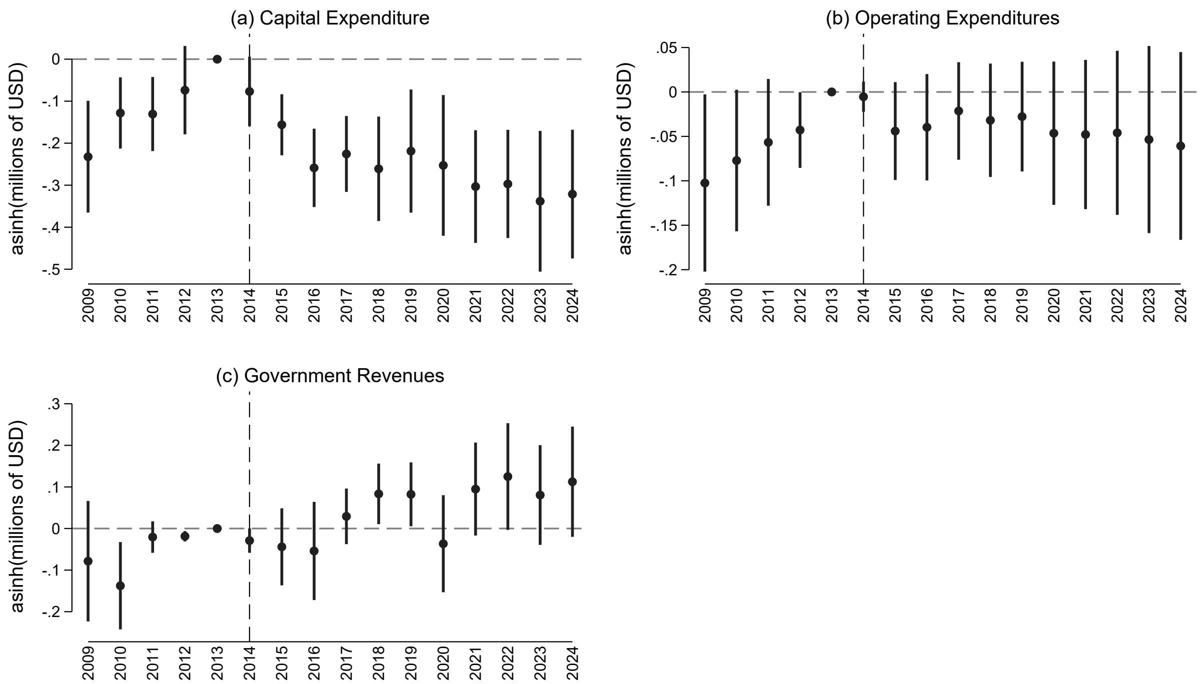
Note: Each subfigure plots kernel densities of the outcome, transformed using the inverse hyperbolic sine transformation, for treated (sanctioned) and control (not sanctioned) Russian oil fields, averaged across 2009-2013. Production distributions are restricted to fields with non-zero production. Reserves distributions are restricted to fields with non-zero reserves. Hellinger Distances between each set of distributions are reported. The Hellinger Distance is a metric used to quantify the difference between two probability distributions based on the square root of the probabilities, and ranges from 0 (identical distributions) to 1 (completely disjoint distributions). Values below 0.25 are generally considered to reflect strong similarity in distributions.

Figure A4: Ownership Switches in Fields Held by Sanctioned Companies in 2013



Note: Figure plots the number of ownership switches per year (2000-2024) for fields held by sanctioned companies in 2013.

Figure A5: Sanction Impacts on Additional Field-Level Outcomes



Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes.

Figure A6: Sanction Impacts on Field-Level Outcomes, by Breakeven Price

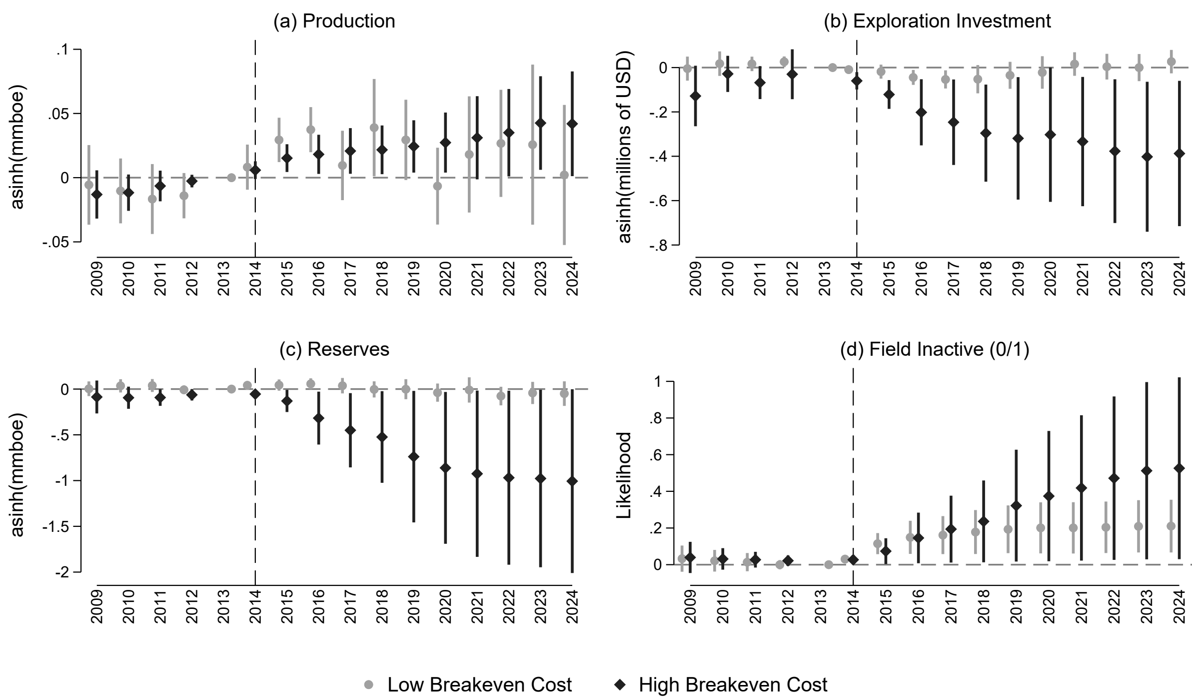


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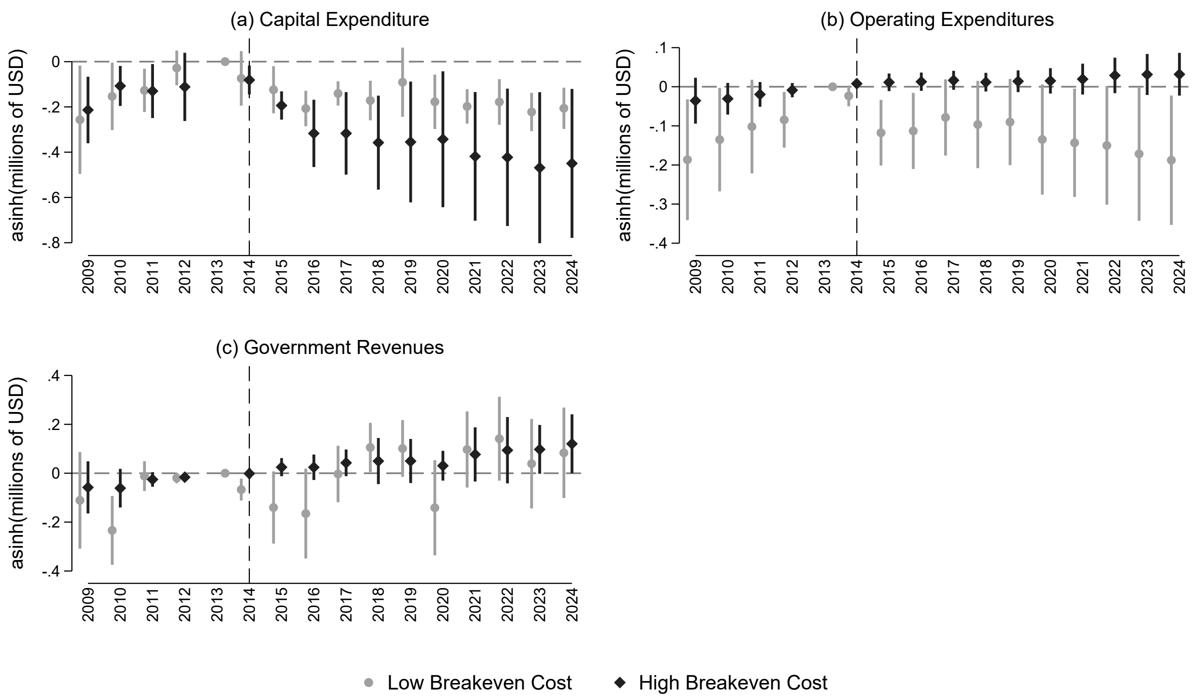
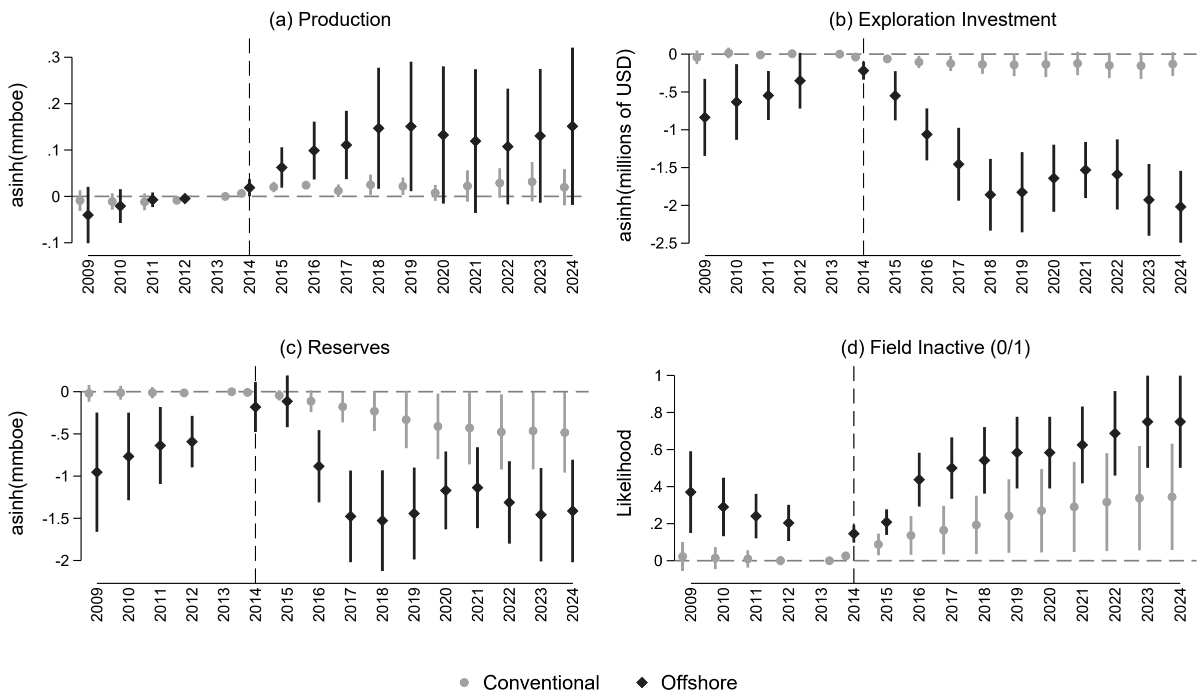
Figure A7: Sanction Impacts on Additional Field-Level Outcomes, by Breakeven Price



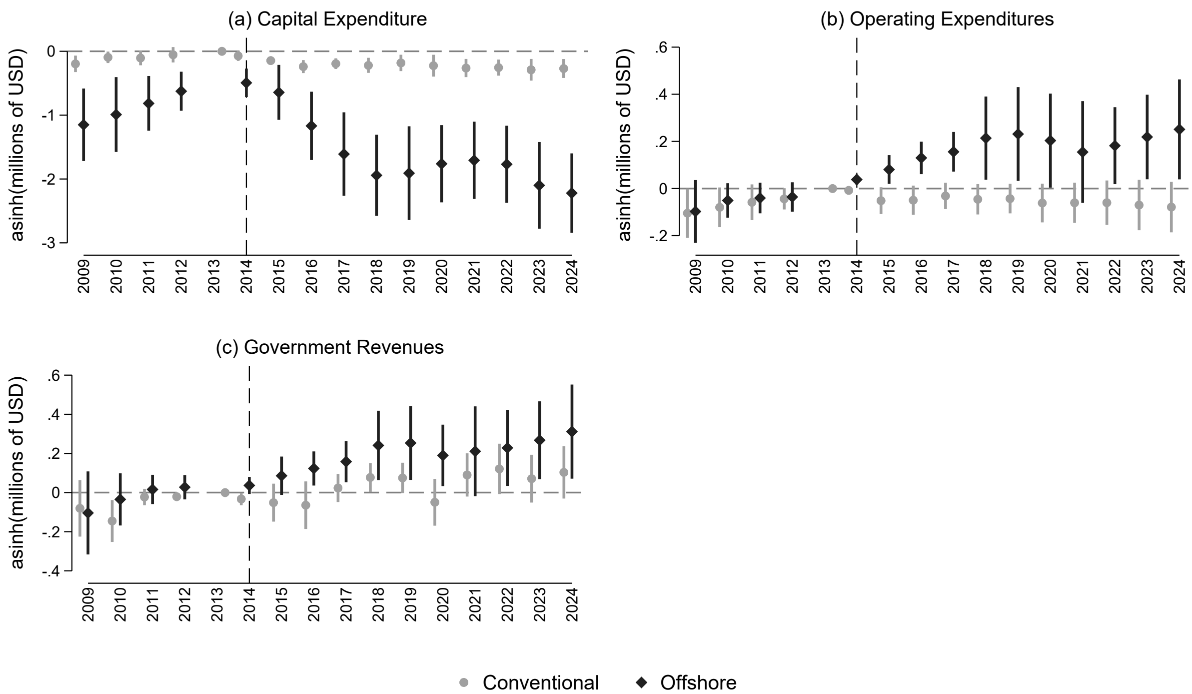
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes. Event studies are estimated separately for fields with below median (low cost) and above median (high cost) FID breakeven prices at the time of discovery, which constitute a best guess of the field's technical complexity and cost of production.

Figure A8: Sanction Impacts on Field-Level Outcomes, by Segment



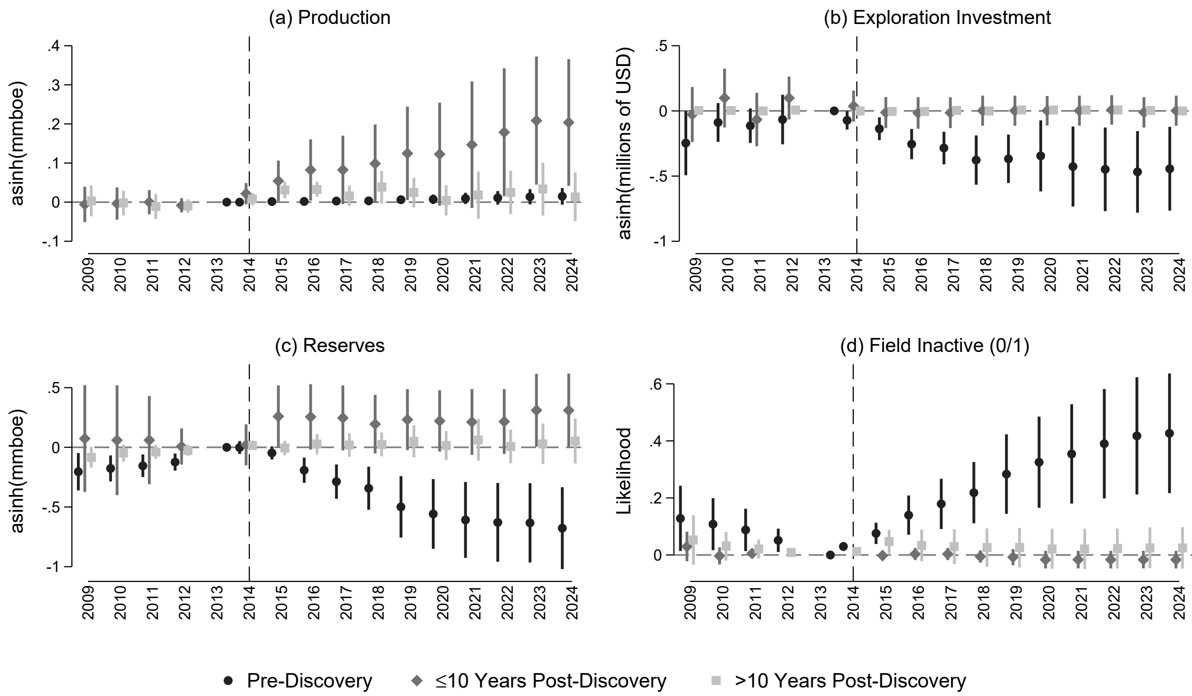
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Event studies are estimated separately for conventional onshore and offshore fields.

Figure A9: Sanction Impacts on Additional Field-Level Outcomes, by Segment



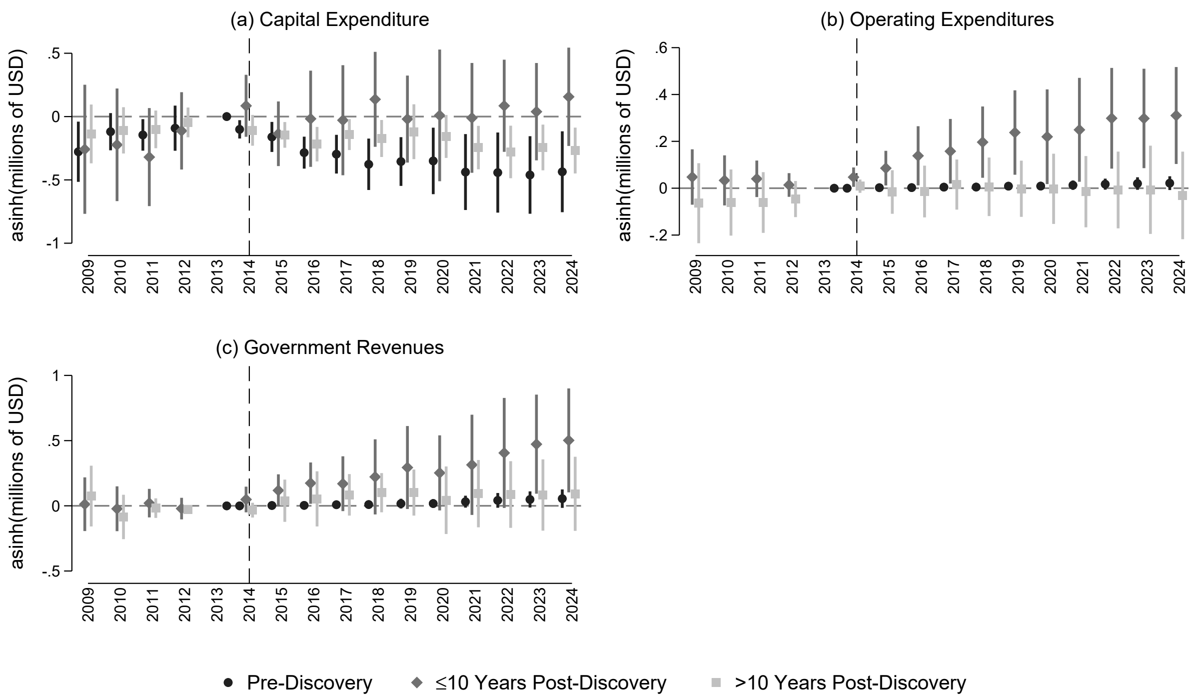
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes. Event studies are estimated separately for conventional onshore and offshore fields.

Figure A10: Sanction Impacts on Field-Level Outcomes, by Field Age



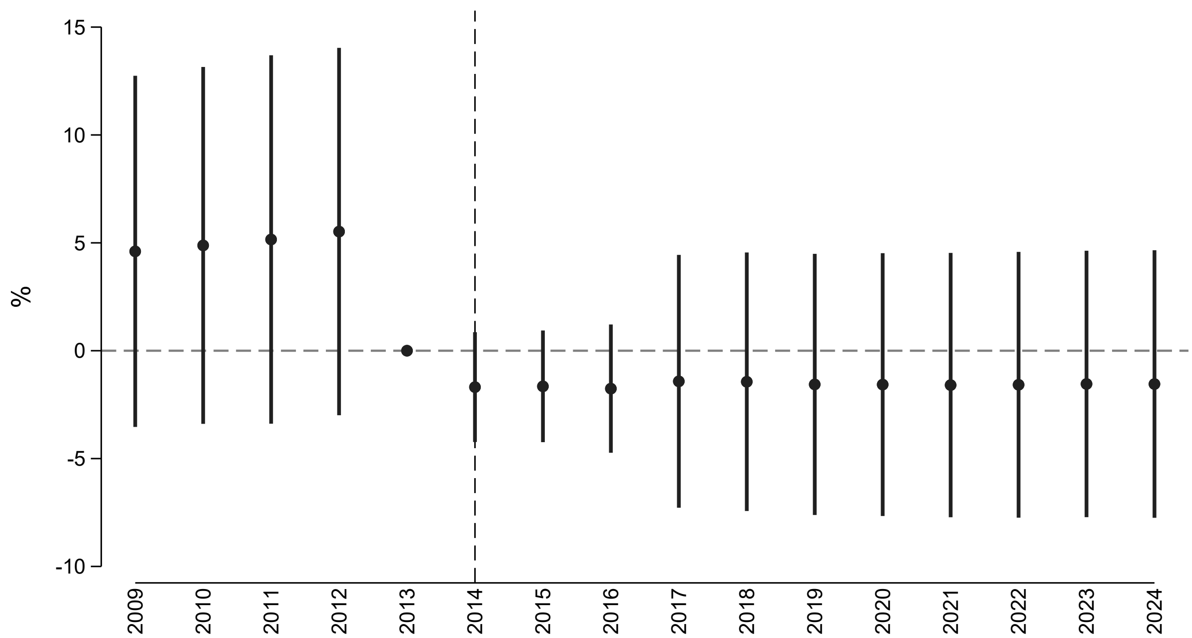
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Event studies are estimated separately for fields based on their status in 2013: unexplored (pre-discovery), recent (up to 10 years post-discovery), and mature (more than 10 years post-discovery).

Figure A11: Sanction Impacts on Additional Field-Level Outcomes, by Field Age



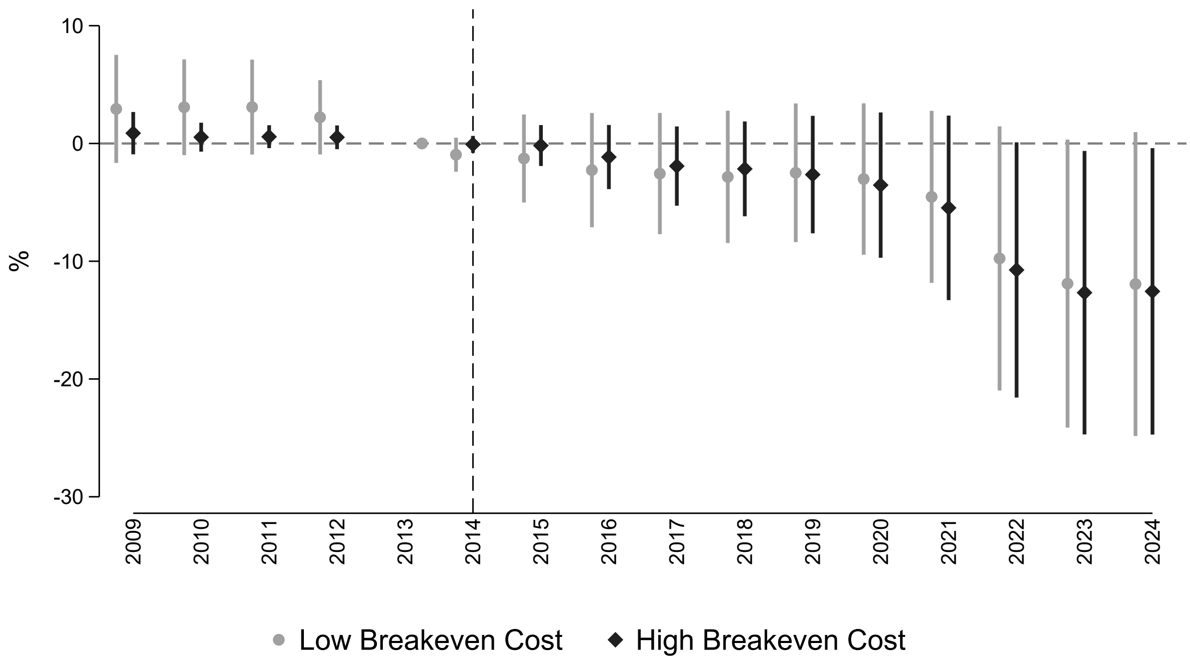
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes. Event studies are estimated separately for fields based on their status in 2013: unexplored (pre-discovery), recent (up to 10 years post-discovery), and mature (more than 10 years post-discovery).

Figure A12: Sanction Impacts on Subsidiary Participation



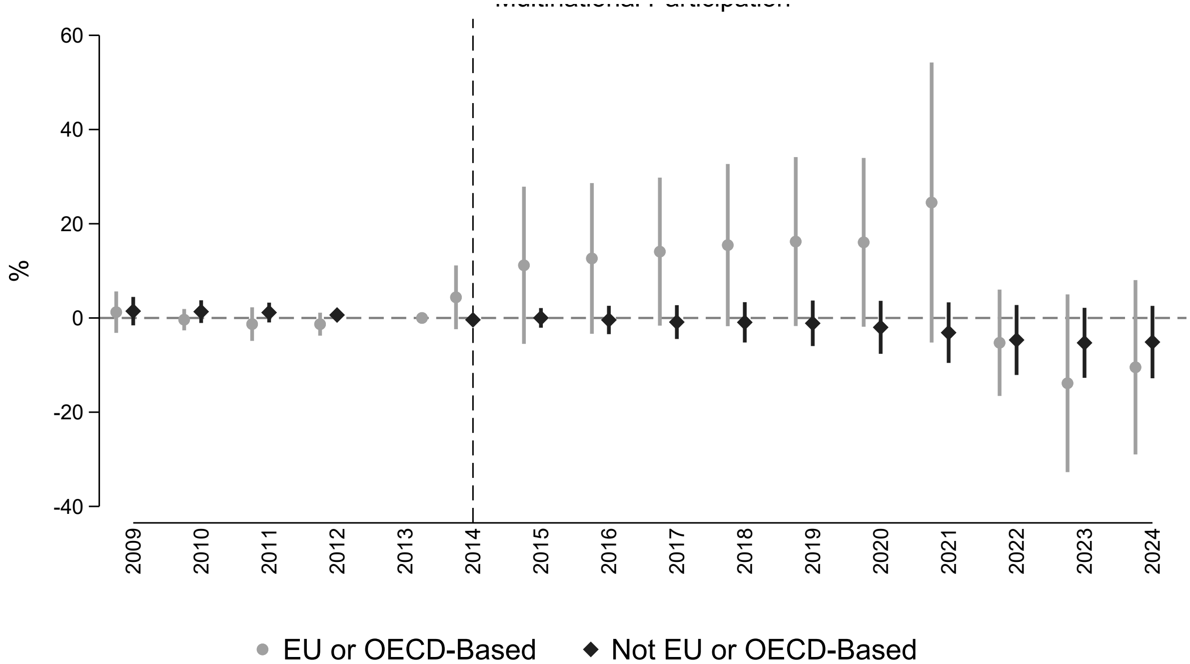
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcome is defined as the percentage of a field's ownership held by companies that are level-1 beneficial subsidiaries of sanctioned companies, based on corporate tree data from S&P Global Market Intelligence (2024).

Figure A13: Sanction Impacts on Multinational Participation, by Breakeven Cost



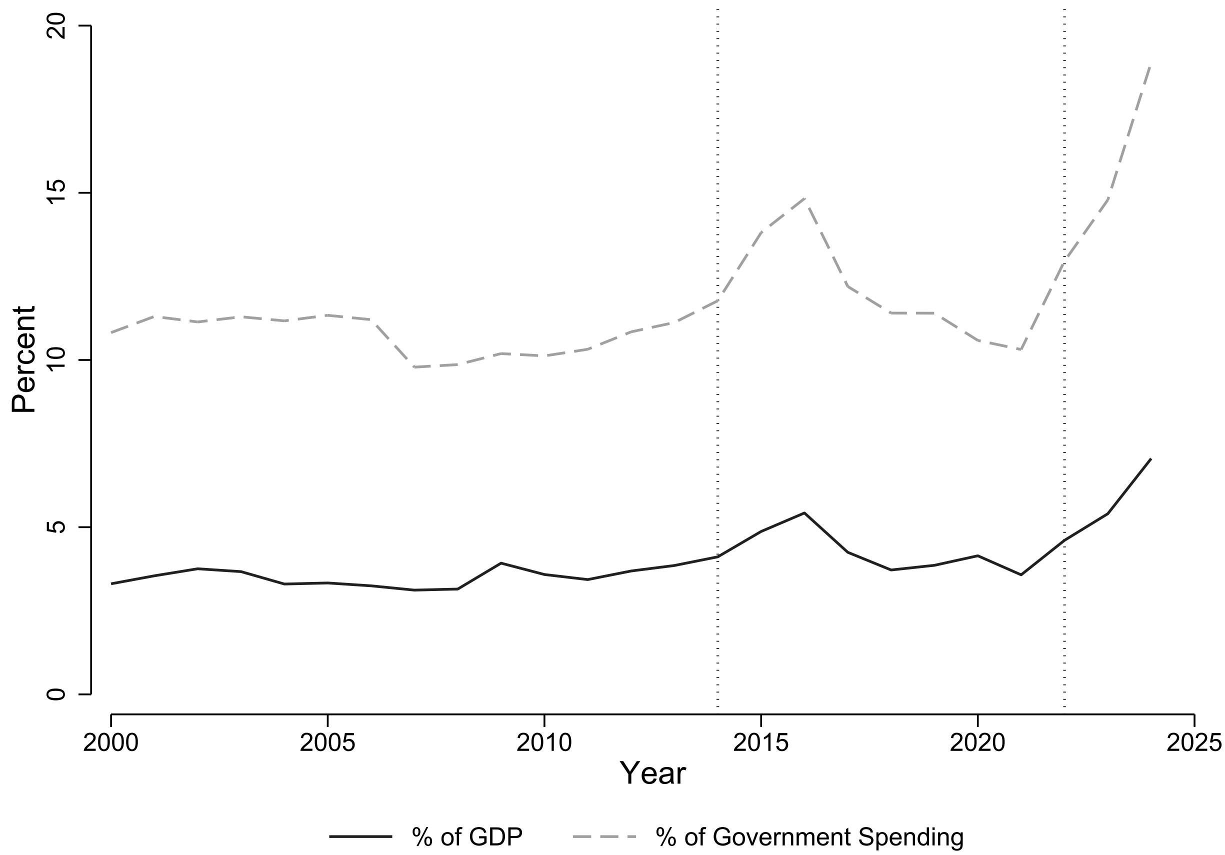
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcome is defined as the percentage of a field's ownership held by countries headquartered outside of Russia. Event studies are estimated separately for fields with below median (low cost) and above median (high cost) FID breakeven prices at the time of discovery, which constitute a best guess of the field's technical complexity and cost of production.

Figure A14: Sanction Impacts on EU/OECD-Based Multinational Participation



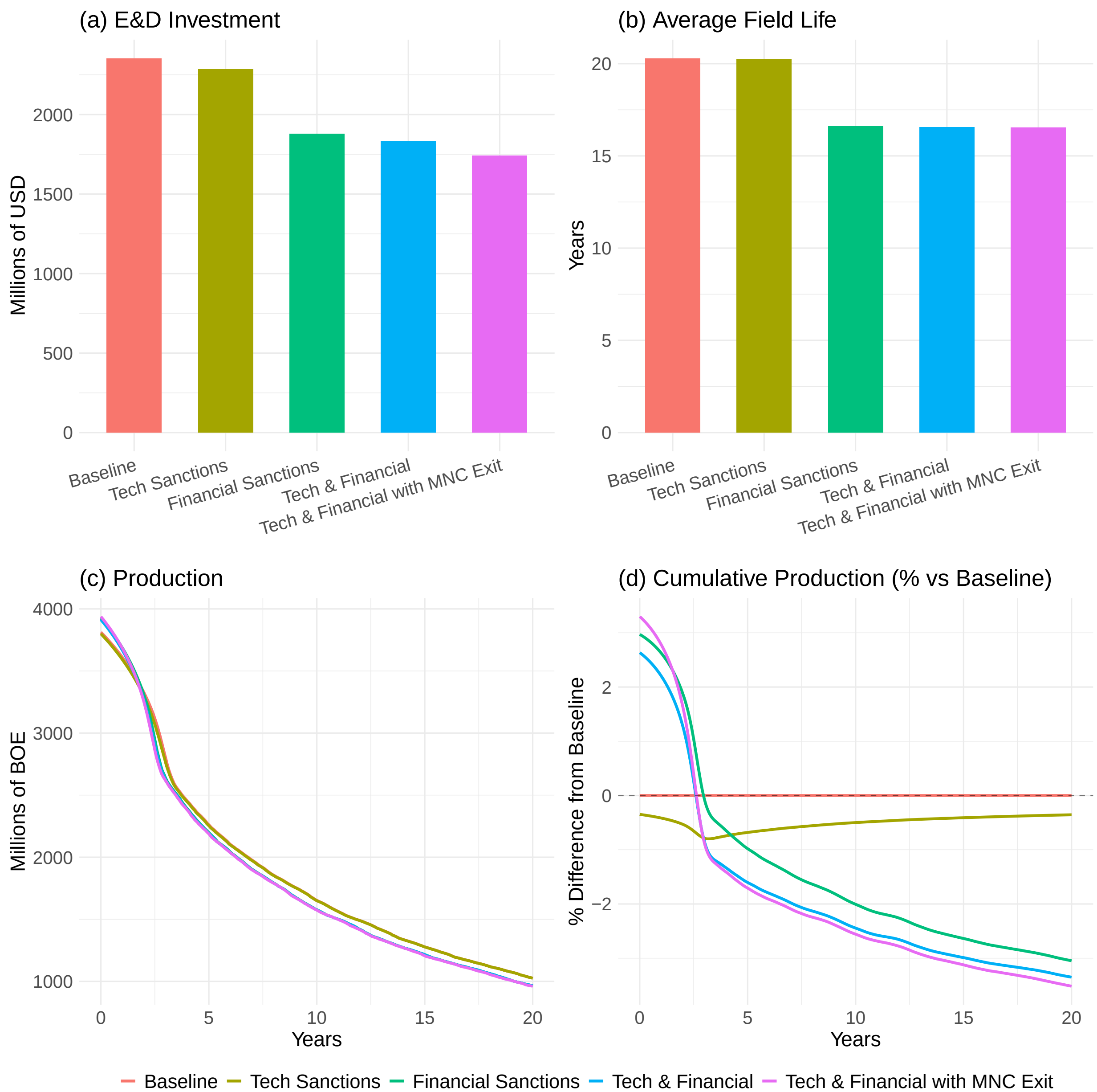
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcome is defined as the percentage of a field's ownership held by countries headquartered outside of Russia. Event studies are estimated separately for fields with and without participation by MNCs based on the European Union or OECD, a proxy for compliance with Western sanction policies.

Figure A15: Russian Military Spending



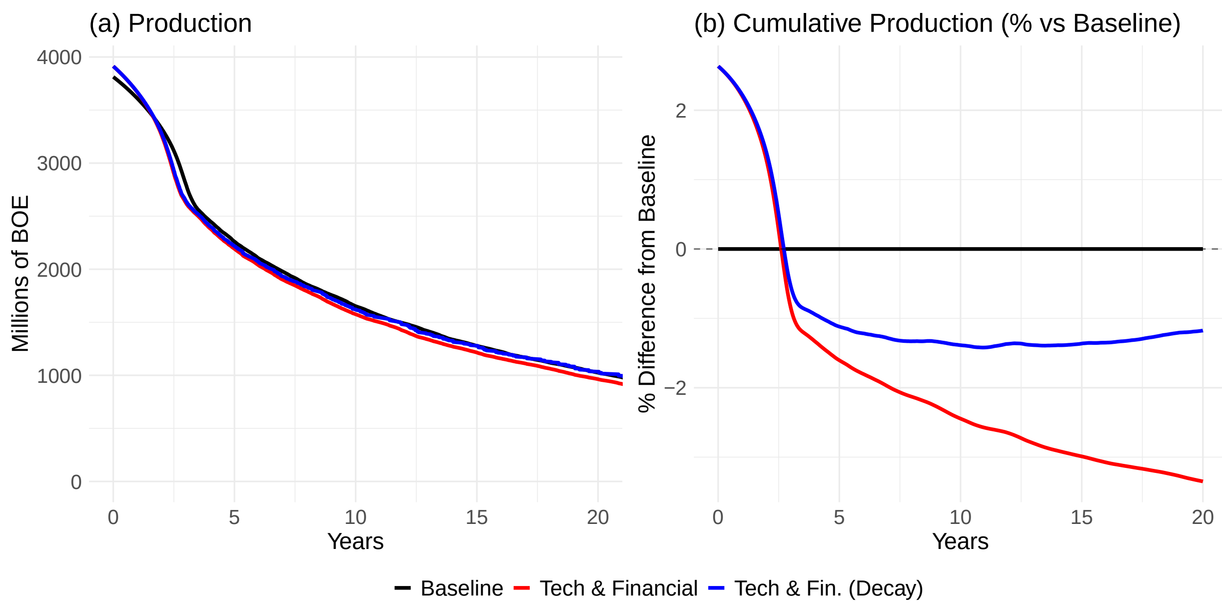
Data source: Stockholm International Peace Research Institute (2025). Horizontal dotted lines represent the onset of Russian military action against Ukraine in 2014 and 2022.

Figure A16: Portfolio-Level Simulation Calibrated to Sanctioned Russian Oil Fields



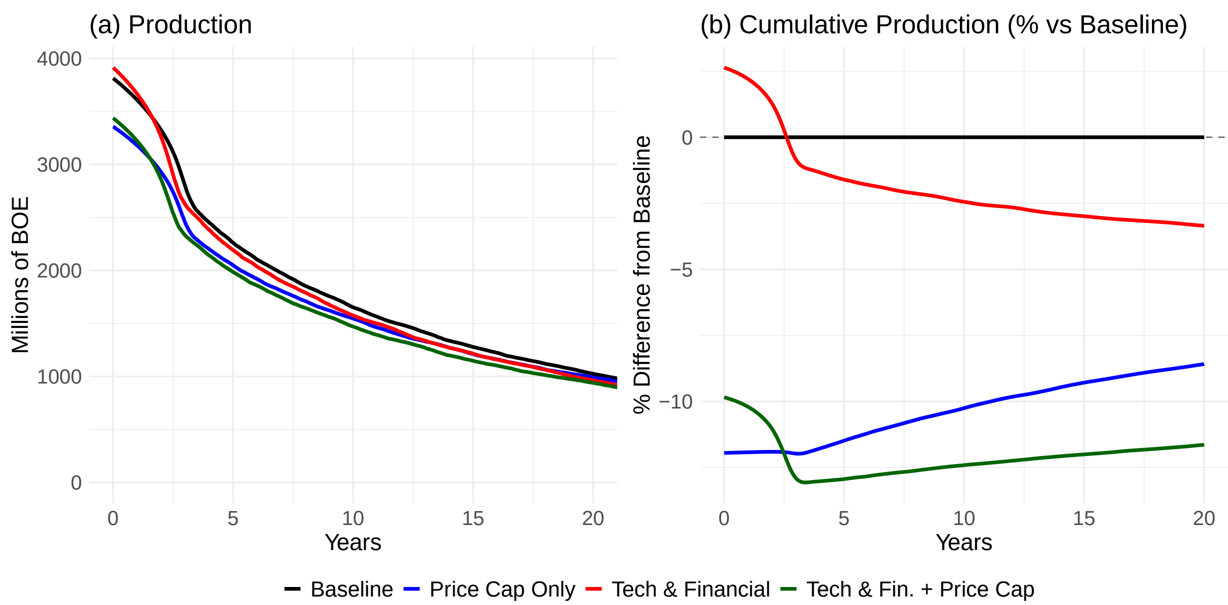
Note: Figure shows simulated E&D investment, abandonment timing, and current and cumulative production for a portfolio of 400 fields matched to empirical moments from the cross-section of sanctioned Russian oil fields in 2013. The net oil price is set to the Brent crude oil price in 2013, $p = 78$ (USD/bbl) with an ad valorem royalty rate of $\gamma = 0.1644$, reflecting observed taxation rates in data from Rystad Energy (2025). Operating costs follow $C(q) = \theta q^{\phi}$ with $\theta = 62.00$ and $\phi = 3.02$, calibrated from field-level panel data on operating expenditures and production. The discount rate is $r = 0.0733$ – the Russian 10-year bond rate in 2013. The reserve–creation function is $G(e) = Ae^{\beta}$ with $A = 2.04$ and $\beta = 0.603$, calibrated from cross-sectional data on peak reserves and cumulative E&D investments. Exploration and development costs are $K(e; \theta, \tau^x) = \theta(1 + \tau^x)e^{\kappa}$ with $\kappa = 1.5$. Original oil in place (R^{cap}) is 522.2. The technology sanction wedge $\tau^x = 0.14$ and financial sanction premium $\Delta r_c = 0.037$ are calibrated to magnitudes from event studies; MNC attenuation parameter $m_{\text{att}} = 0.35$ is calibrated using field-level panel data on MNC participation and outcomes pre/post sanctions.

Figure A17: Production Dynamics Under Permanent vs Decaying Sanctions



Note: Panel (a) shows production over time. Panel (b) shows the percentage deviation from baseline in cumulative production over time. The decay scenario models gradual sanction weakening over 20 years as firms find alternative suppliers and financing. Technology sanctions decay linearly to zero by year 20: $\tau(t) = \tau_0 \times (1 - 0.05t)$. Financial sanctions decay by 50% by year 20: $\Delta r(t) = \Delta r_0 \times (1 - 0.025t)$. Simulated portfolio of 100 fields calibrated to 2013 data from sanctioned Russian oil companies using model parameters specified in Appendix Table B16.

Figure A18: Production Dynamics Under Input Sanctions with US$60 Price Cap



Note: Panel (a) shows production over time. Panel (b) shows the percentage deviation from baseline in cumulative production over time. The price cap scenario imposes a $60/barrel ceiling on Russian oil sales in addition to technology and financial sanctions (contrasting with the baseline model price of $78/barrel, reflecting the average Brent crude price in 2013). Simulated portfolio of 100 fields calibrated to 2013 data from sanctioned Russian oil companies using model parameters specified in Appendix Table B16.

B Supplementary Tables

Table B1: Characteristics of Sanctioned vs Non-Sanctioned Fields (Pre and Post-Matching)

	Pre-Matching			**Post-Matching**		
	Sanctioned	**Non-Sanct.**	**NMD**	**Sanctioned**	**Non-Sanct.**	**NMD**
Total Production (millions of boe)	2.18	0.24	0.15	0.80	0.33	0.12
Oil Production	0.98	0.15	0.21	0.67	0.11	0.30
Gas Production	1.13	0.07	0.09	0.11	0.20	-0.02
NGL Production	0.03	0.00	0.08	0.01	0.01	0.04
Capex (millions of USD)	14.94	1.74	0.17	10.21	1.95	0.14
Opex	27.99	2.10	0.13	8.47	2.74	0.13
Exploration	86.19	7.77	0.18	35.38	8.20	0.23
Royalties	37.81	3.09	0.16	14.12	2.62	0.25
Government Profit Oil	0.26	0.01	0.04	0.06	0.01	0.02
Income Tax	3.96	0.59	0.11	1.84	0.60	0.14
Discovery Volume (millions of boe)	0.88	0.23	0.03	0.58	0.22	0.02
Technical Reserves (millions of boe)	72.16	10.40	0.15	28.36	9.94	0.14
Breakeven Cost (USD)	61.62	56.00	0.23	61.98	56.13	0.18
Offshore (0/1)	0.04	0.01	0.23	0.04	0.05	-0.02
Water Depth for Offshore (meters)	115.28	143.03	-0.21	116.60	116.86	0.02
Shale Play (0/1)	0.00	0.01	-0.07	0.00	0.01	-0.02
Arctic (0/1)	0.02	0.01	0.17	0.02	0.02	-0.01
Latitude (degrees)	57.71	56.99	0.06	57.64	57.69	-0.06
Night Lights (millions of USD, 10km)	481.15	333.68	0.23	470.75	337.77	0.22
Flaring (BCM, 10km)	0.00	0.00	0.09	0.00	0.00	0.09
n (sample size)	3,516	4,797		3,447	4,776	

Note: Table reports sample mean values over the 2009-2013 period preceding sanctioning in 2014. Units are defined as in the row above where not otherwise specified. NMD refers to the normalized mean difference between groups, calculated as the difference in means between sanctioned and non-sanctioned fields, divided by the square root of the average of their standard deviations. NMD values ≤ 0.25 are generally considered to indicate balance between groups. Matching involves coarsened exact matching on province, onshore/offshore status, and deciles of pre-treatment production (total), exploration, reserves, and government payments (total). Matching weights are applied when computing post-matching means.

Table B2: Main Results: Sanction Effects on Oil Field Outcomes

	(1) Production		(2) Reserves		(3) Exploration		(4) Inactive	
	β	SE	β	SE	β	SE	β	SE
2009	-0.010	(0.011)	-0.062	(0.043)	-0.072	(0.042)	0.041	(0.038)
2010	-0.011	(0.008)	-0.047	(0.031)	-0.007	(0.026)	0.029	(0.029)
2011	-0.012	(0.008)	-0.041	(0.023)	-0.028	(0.020)	0.022	(0.022)
2012	-0.008	(0.004)	-0.041**	(0.016)	-0.004	(0.031)	0.013	(0.012)
2014	0.007	(0.004)	-0.006	(0.013)	-0.036**	(0.012)	0.028**	(0.011)
2015	0.022***	(0.006)	-0.038	(0.030)	-0.072***	(0.022)	0.088**	(0.030)
2016	0.028***	(0.005)	-0.119	(0.068)	-0.126**	(0.043)	0.138*	(0.054)
2017	0.017*	(0.007)	-0.191	(0.098)	-0.151**	(0.054)	0.166*	(0.068)
2018	0.031**	(0.011)	-0.242*	(0.123)	-0.176**	(0.066)	0.194*	(0.081)
2019	0.028**	(0.009)	-0.340	(0.174)	-0.175*	(0.076)	0.242*	(0.102)
2020	0.014	(0.009)	-0.415*	(0.198)	-0.161	(0.088)	0.270*	(0.115)
2021	0.027	(0.017)	-0.432*	(0.220)	-0.162*	(0.079)	0.291*	(0.124)
2022	0.033*	(0.016)	-0.482*	(0.227)	-0.187*	(0.088)	0.317*	(0.135)
2023	0.036	(0.021)	-0.469*	(0.233)	-0.200*	(0.091)	0.339*	(0.144)
2024	0.026	(0.019)	-0.486*	(0.243)	-0.180*	(0.085)	0.345*	(0.147)
Observations	206200		208425		206200		208425	
Mean of Dep. Var.	.1719		.9957		.1714		.3359	
Year FE	Yes		Yes		Yes		Yes	
Field FE	Yes		Yes		Yes		Yes	
Base Year	2013		2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B3: High Cost Fields: Sanction Effects on Oil Field Outcomes

	(1) Production		(2) Reserves		(3) Exploration		(4) Inactive	
	β	SE	β	SE	β	SE	β	SE
2009	-0.013	(0.010)	-0.086	(0.092)	-0.128	(0.070)	0.039	(0.043)
2010	-0.012	(0.007)	-0.095	(0.062)	-0.029	(0.042)	0.031	(0.030)
2011	-0.006	(0.006)	-0.093*	(0.046)	-0.068	(0.038)	0.027	(0.022)
2012	-0.003	(0.002)	-0.063*	(0.032)	-0.030	(0.057)	0.022	(0.015)
2014	0.006	(0.004)	-0.054**	(0.019)	-0.060**	(0.020)	0.027*	(0.013)
2015	0.015**	(0.006)	-0.130*	(0.062)	-0.121***	(0.033)	0.074*	(0.036)
2016	0.018*	(0.008)	-0.317*	(0.147)	-0.202**	(0.076)	0.146*	(0.070)
2017	0.021*	(0.009)	-0.450*	(0.207)	-0.246*	(0.098)	0.194*	(0.093)
2018	0.022*	(0.010)	-0.524*	(0.255)	-0.296**	(0.112)	0.236*	(0.114)
2019	0.024*	(0.010)	-0.739*	(0.367)	-0.319*	(0.141)	0.322*	(0.156)
2020	0.027*	(0.012)	-0.861*	(0.423)	-0.303	(0.155)	0.374*	(0.181)
2021	0.031	(0.017)	-0.925*	(0.463)	-0.334*	(0.149)	0.419*	(0.202)
2022	0.035*	(0.017)	-0.969*	(0.485)	-0.377*	(0.165)	0.472*	(0.227)
2023	0.043*	(0.019)	-0.977*	(0.495)	-0.402*	(0.173)	0.513*	(0.247)
2024	0.042*	(0.021)	-1.006*	(0.512)	-0.387*	(0.167)	0.526*	(0.253)
Observations	102575		104520		102575		104520	
Mean of Dep. Var.	.0485		.9422		.2268		.2869	
Year FE	Yes		Yes		Yes		Yes	
Field FE	Yes		Yes		Yes		Yes	
Base Year	2013		2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B4: Low Cost Fields: Sanction Effects on Oil Field Outcomes

	(1) Production		(2) Reserves		(3) Exploration		(4) Inactive	
	β	SE	β	SE	β	SE	β	SE
2009	-0.006	(0.016)	0.003	(0.041)	-0.005	(0.028)	0.033	(0.036)
2010	-0.010	(0.013)	0.035	(0.037)	0.018	(0.028)	0.021	(0.030)
2011	-0.017	(0.014)	0.039	(0.036)	0.017	(0.017)	0.014	(0.025)
2012	-0.014	(0.009)	-0.008	(0.024)	0.026*	(0.012)	-0.000	(0.013)
2014	0.008	(0.009)	0.041	(0.023)	-0.009	(0.008)	0.030**	(0.010)
2015	0.029***	(0.009)	0.044	(0.031)	-0.018	(0.016)	0.115***	(0.029)
2016	0.037***	(0.009)	0.057	(0.030)	-0.044**	(0.017)	0.149**	(0.046)
2017	0.010	(0.014)	0.037	(0.043)	-0.053*	(0.021)	0.161**	(0.053)
2018	0.039*	(0.019)	-0.004	(0.045)	-0.052	(0.032)	0.178**	(0.061)
2019	0.029	(0.016)	-0.002	(0.056)	-0.035	(0.031)	0.193**	(0.066)
2020	-0.007	(0.015)	-0.039	(0.051)	-0.022	(0.037)	0.201**	(0.071)
2021	0.018	(0.023)	-0.010	(0.070)	0.016	(0.027)	0.201**	(0.071)
2022	0.027	(0.021)	-0.076	(0.052)	0.004	(0.030)	0.204**	(0.072)
2023	0.026	(0.032)	-0.043	(0.062)	-0.000	(0.031)	0.209**	(0.073)
2024	0.002	(0.028)	-0.050	(0.068)	0.027	(0.027)	0.210**	(0.073)
Observations	103625		103905		103625		103905	
Mean of Dep. Var.	.294		1.0495		.1166		.3851	
Year FE	Yes		Yes		Yes		Yes	
Field FE	Yes		Yes		Yes		Yes	
Base Year	2013		2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B5: Conventional Fields: Sanction Effects on Oil Field Outcomes

	(1) Production		(2) Reserves		(3) Exploration		(4) Inactive	
	β	SE	β	SE	β	SE	β	SE
2009	-0.009	(0.011)	-0.019	(0.051)	-0.043	(0.046)	0.023	(0.040)
2010	-0.011	(0.009)	-0.012	(0.042)	0.016	(0.036)	0.014	(0.030)
2011	-0.012	(0.009)	-0.011	(0.034)	-0.010	(0.022)	0.009	(0.024)
2012	-0.008	(0.005)	-0.014	(0.020)	0.006	(0.027)	0.000	(0.013)
2014	0.006	(0.004)	-0.008	(0.012)	-0.039**	(0.014)	0.026**	(0.010)
2015	0.020***	(0.006)	-0.044	(0.031)	-0.063***	(0.017)	0.088**	(0.030)
2016	0.024***	(0.005)	-0.113	(0.066)	-0.105*	(0.041)	0.136*	(0.053)
2017	0.012	(0.007)	-0.178	(0.095)	-0.124*	(0.051)	0.165*	(0.067)
2018	0.025*	(0.011)	-0.232	(0.119)	-0.136*	(0.063)	0.193*	(0.080)
2019	0.022*	(0.010)	-0.331	(0.173)	-0.142	(0.076)	0.241*	(0.101)
2020	0.008	(0.009)	-0.411*	(0.198)	-0.134	(0.087)	0.270*	(0.115)
2021	0.022	(0.017)	-0.429	(0.220)	-0.123	(0.079)	0.290*	(0.124)
2022	0.029	(0.016)	-0.477*	(0.227)	-0.149	(0.086)	0.316*	(0.135)
2023	0.032	(0.022)	-0.464*	(0.232)	-0.153	(0.090)	0.338*	(0.143)
2024	0.020	(0.020)	-0.484*	(0.242)	-0.131	(0.081)	0.344*	(0.146)
Observations	200400		202075		200400		202075	
Mean of Dep. Var.	.1735		.9800		.151		.3385	
Year FE	Yes		Yes		Yes		Yes	
Field FE	Yes		Yes		Yes		Yes	
Base Year	2013		2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B6: Offshore Fields: Sanction Effects on Oil Field Outcomes

	(1) Production		(2) Reserves		(3) Exploration		(4) Inactive	
	β	SE	β	SE	β	SE	β	SE
2009	-0.040	(0.031)	-0.954**	(0.360)	-0.836**	(0.260)	0.370**	(0.113)
2010	-0.021	(0.019)	-0.767**	(0.265)	-0.633*	(0.255)	0.290***	(0.081)
2011	-0.007	(0.008)	-0.638**	(0.233)	-0.547***	(0.165)	0.241***	(0.061)
2012	-0.005	(0.003)	-0.592***	(0.156)	-0.352	(0.188)	0.204***	(0.050)
2014	0.019*	(0.009)	-0.182	(0.151)	-0.218***	(0.061)	0.146***	(0.025)
2015	0.062**	(0.022)	-0.114	(0.156)	-0.550***	(0.166)	0.208***	(0.035)
2016	0.099**	(0.032)	-0.883***	(0.218)	-1.061***	(0.175)	0.438***	(0.074)
2017	0.111**	(0.038)	-1.477***	(0.277)	-1.456***	(0.246)	0.500***	(0.085)
2018	0.147*	(0.067)	-1.528***	(0.304)	-1.859***	(0.242)	0.542***	(0.092)
2019	0.151*	(0.071)	-1.443***	(0.278)	-1.826***	(0.271)	0.583***	(0.099)
2020	0.132	(0.075)	-1.169***	(0.236)	-1.641***	(0.227)	0.583***	(0.099)
2021	0.119	(0.079)	-1.137***	(0.245)	-1.532***	(0.189)	0.625***	(0.106)
2022	0.107	(0.064)	-1.312***	(0.249)	-1.591***	(0.237)	0.688***	(0.116)
2023	0.131	(0.074)	-1.458***	(0.282)	-1.927***	(0.242)	0.750***	(0.127)
2024	0.151	(0.087)	-1.413***	(0.310)	-2.018***	(0.243)	0.750***	(0.127)
Observations	5250		5250		5250		5250	
Mean of Dep. Var.	.1213		1.7579		.8874		.1952	
Year FE	Yes		Yes		Yes		Yes	
Field FE	Yes		Yes		Yes		Yes	
Base Year	2013		2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B7: Sanction Effects on Multinational Participation, by Segment

	(1) MNC Share: Offshore		(2) MNC Share: Conventional	
	β	SE	β	SE
2009	-5.345	(5.963)	2.373	(1.777)
2010	-6.807	(4.893)	2.335	(1.547)
2011	-6.259	(4.645)	2.354	(1.536)
2012	-5.057	(3.554)	1.813	(1.351)
2014	-0.250	(0.906)	-0.608	(0.598)
2015	-5.614***	(1.215)	-0.722	(1.382)
2016	-9.993***	(1.847)	-1.640	(1.924)
2017	-12.076***	(2.172)	-2.145	(2.131)
2018	-12.076***	(2.172)	-2.399	(2.438)
2019	-12.076***	(2.172)	-2.475	(2.717)
2020	-12.078***	(2.171)	-3.209	(3.129)
2021	-14.724***	(2.494)	-4.919	(3.730)
2022	-22.736***	(4.504)	-10.036	(5.494)
2023	-24.507***	(5.032)	-11.941*	(6.046)
2024	-24.507***	(5.032)	-11.942	(6.236)
Observations	5250		202075	
Mean of Dep. Var.	12.795		10.4813	
Year FE	Yes		Yes	
Field FE	Yes		Yes	
Base Year	2013		2013	

Notes: Each panel (1-2) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are percentages. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B8: Sanction Effects on Local Economic Activity

	(1) Nightlight 0-5km		(2) Nightlight 5-15km		(3) Nightlight 15-25km	
	β	SE	β	SE	β	SE
2009	0.0037	(0.0036)	0.0011	(0.0027)	0.0006	(0.0020)
2010	0.0026	(0.0027)	0.0014	(0.0020)	0.0008	(0.0017)
2011	0.0006	(0.0017)	0.0006	(0.0013)	0.0001	(0.0013)
2012	-0.0010	(0.0009)	-0.0009	(0.0006)	-0.0008	(0.0005)
2014	0.0024**	(0.0009)	0.0010	(0.0006)	0.0011*	(0.0005)
2015	0.0056***	(0.0016)	0.0025**	(0.0009)	0.0026**	(0.0009)
2016	0.0060***	(0.0017)	0.0029***	(0.0008)	0.0033**	(0.0011)
2017	0.0055**	(0.0019)	0.0022*	(0.0010)	0.0031*	(0.0013)
2018	0.0044	(0.0023)	0.0014	(0.0013)	0.0033*	(0.0013)
2019	0.0065*	(0.0029)	0.0021	(0.0015)	0.0042**	(0.0016)
Observations	149220		149220		149220	
Mean of Dep. Var.	4.1829		6.2738		7.0165	
Year FE	Yes		Yes		Yes	
Field FE	Yes		Yes		Yes	
Base Year	2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B9: Sanction Effects on Gas Flaring

	(1) BCM Sum	
	β	SE
2012	0.002***	(0.001)
2014	-0.000	(0.001)
2015	-0.001	(0.001)
2016	0.001	(0.002)
2017	-0.000	(0.002)
2018	-0.000	(0.002)
2019	-0.003	(0.002)
2020	0.001	(0.003)
2021	0.006	(0.003)
2022	0.006	(0.003)
2023	0.007*	(0.004)
2024	0.008*	(0.004)
Observations	44551	
Mean of Dep. Var.	.0101	
Year FE	Yes	
Field FE	Yes	
Base Year	2013	

Notes: Table reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcome BCM Sum measures billions of cubic meters of flared gas, transformed using the inverse hyperbolic sine transformation. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B10: Sanction Impacts on Field-Level Outcomes with Untransformed Outcomes

	(1) Production		(2) Exploration		(3) Reserves	
	β	SE	β	SE	β	SE
2009	-0.006	(0.016)	-0.061	(0.048)	-0.494	(0.506)
2010	-0.013	(0.012)	-0.014	(0.036)	-0.282	(0.428)
2011	-0.014	(0.011)	-0.031	(0.028)	-0.291	(0.350)
2012	-0.006	(0.004)	-0.016	(0.033)	-0.211	(0.186)
2014	0.013***	(0.003)	-0.043**	(0.017)	0.096	(0.234)
2015	0.035***	(0.009)	-0.070***	(0.020)	0.249	(0.290)
2016	0.044***	(0.009)	-0.124**	(0.046)	0.136	(0.424)
2017	0.034**	(0.013)	-0.149**	(0.056)	-0.355	(0.578)
2018	0.048**	(0.018)	-0.165*	(0.069)	-0.801	(0.728)
2019	0.056**	(0.018)	-0.165*	(0.079)	-1.139	(1.036)
2020	0.033	(0.018)	-0.153	(0.090)	-1.774	(1.057)
2021	0.043	(0.027)	-0.149	(0.081)	-1.852	(1.301)
2022	0.057*	(0.029)	-0.173	(0.090)	-2.453*	(1.234)
2023	0.057	(0.032)	-0.187*	(0.093)	-2.546	(1.345)
2024	0.046	(0.032)	-0.165	(0.086)	-2.875*	(1.434)
Observations	206200		206200		208425	
Mean of Dep. Var.	.246		.1651		8.7633	
Year FE	Yes		Yes		Yes	
Field FE	Yes		Yes		Yes	
Base Year	2013		2013		2013	

Notes: Each panel (1-4) reports coefficient estimates and standard errors from the event study described in Equation 4, where field-year outcomes are regressed on relative time indicators around 2014, as well as year and time fixed effects, using the estimator developed in Callaway and Sant'Anna (2021). Standard errors are clustered at the level of the company that operated the field in 2013. Outcomes are untransformed and winsorized at 2nd and 98th percentiles. The omitted base year is 2013. Not-yet-treated units are included as controls. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B11: Single-Field Simulation Parameters

Parameter	Symbol	Value	Description (generic illustrative values)
Market Conditions			
Oil price	p	\$75/barrel	Brent crude price
Royalty rate	γ	0.30	Fiscal regime
Field Characteristics			
Complexity	θ	15	Breakeven cost
Cost curvature	ϕ	2.2	Production cost convexity
Financial Parameters			
Discount rate	r	0.10	Pre-sanction cost of capital
Reserve Creation			
E&D efficiency	A	1.6	Reserve creation efficiency
E&D curvature	β	0.6	Diminishing returns to investment
Cost curvature	κ	1.5	E&D cost convexity
Sanction Intensities			
Technology wedge	τ^x	1.0	Input cost increase (100%)
Financial premium	Δr_c	0.15	Discount rate increase (1500 bp)
MNC attenuation	m	0.60	Joint venture attenuation (60%)

Single-Field Simulation Parameter Explanations: The reserve creation function $G(e) = Ae^{\beta}$ with $\beta = 0.6 < 1$ exhibits diminishing returns, reflecting geological constraints on how much additional E&D investment can generate producible reserves. The E&D cost function $K(e) = \theta e^{\kappa}$ with $\kappa = 1.5 > 1$ captures increasing marginal costs of drilling and infrastructure development that scale with field complexity θ, which is proxied by breakeven cost at time of discovery. Similarly, the production cost function $C(q) = \theta q^{\phi}$ with $\phi = 2.2 > 1$ reflects how increasing oil production from a field requires progressively more expensive enhanced recovery techniques. A technology sanction wedge $\tau = 0.60$ doubles effective E&D costs, reflecting how sanctioned firms must source equipment from more expensive alternative suppliers or use inferior domestic substitutes. A financial sanction premium $\Delta r_c = 0.15$ reflects increased borrowing costs. The MNC attenuation parameter $m = 0.60$ implies that joint venture partnerships reduce both technology and financing wedges by 60%.

Table B12: Empirical and Simulated Moments Comparison

Moment	Data	Model
Field complexity (mean)	62.00	62.50
Field complexity (SD)	56.50	57.70
Geological capacity (mean, M BOE)	522.20	511.50
Geological capacity (SD, M BOE)	1166.30	865.50
Development rate (%)	73.80	72.20
MNC partnership rate (%)	45.80	48.50

Notes: Data moments are computed from the empirical distribution of Russian oil fields operated by sanctioned companies in 2013. Model moments are generated from the simulated portfolio of 400 fields calibrated to match empirical characteristics.

Table B13: Misallocation

	Pre-2014	Post-2013
	(1)	(2)
Panel A: Sanctioned Fields		
Log Cumulative E&D Investment	0.603***	0.314***
	(0.025)	(0.058)
Observations	3089	416
Scale Parameter (A)	2.04	112.85
Controls	Yes	Yes
Adjusted R-squared	0.503	0.641
Panel B: Non-Sanctioned Fields		
Log Cumulative E&D Investment	0.394***	0.239***
	(0.029)	(0.034)
Observations	3232	1564
Scale Parameter (A)	1.20	7.38
Controls	Yes	Yes
Adjusted R-squared	0.472	0.390

Notes: Dependent variable is the log of peak reserves (maximum technical reserves observed before production depletion). Cumulative E&D Investment includes exploration and capital expenditure. Each observation represents one oil field at the year it achieved peak reserves. Controls include breakeven cost, original oil in place, water depth, and latitude. The scale parameter A is calculated as exp(constant). Standard errors are robust to heteroskedasticity. Sample includes Russian oil fields operated by companies based on their 2013 sanctioned status. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table B14: Estimation of Production Cost Convexity Parameter

	(1) First Stage	(2) IV (2SLS)
Brent Crude Oil Price	0.007***	
	(0.000)	
Log Extraction Rate		3.022***
		(0.115)
Observations	16461	15919
First-stage F-stat	372.1	
Fields	1,336	1,320

Notes: Dependent variable: Column (1) log extraction rate (barrels produced per barrel of reserves); Column (2) log operating costs per barrel of reserves. All specifications include field fixed effects. Standard errors clustered at the field level are reported in parentheses. Sample: Russian oil fields held by sanctioned companies as of 2013, observed between 2000-2013.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B15: Multinational Impact Calibration

	(1) Production	(2) Exploration	(3) Inactive
MNC%	-0.00051***	0.00133***	-0.00163***
	(0.00008)	(0.00007)	(0.00005)
Post2013	0.03180***	-0.02064***	-0.01671***
	(0.00567)	(0.00524)	(0.00347)
MNC% X Post2013	0.00149***	0.00120***	-0.00478***
	(0.00029)	(0.00027)	(0.00017)
R-squared	0.795	0.349	0.367
Observations	36,325	36,325	36,950
Mean of dependent variable	.2925	.1454	.1454
Field FE	Yes	Yes	Yes

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

Notes: Each panel (1-3) reports coefficient estimates with standard errors in parentheses from difference-in-differences specification that regresses outcomes (total oil and gas production, exploration investment, and inactive field indicator) on the contemporaneous MNC participation share, a post-2013 indicator capturing the sanction regime, and an interaction of these two terms. All specifications include field fixed effects. The sample is restricted to a balanced panel of fields held by sanctioned companies in 2013. Outcomes are transformed using the inverse hyperbolic sine function, and standard errors are clustered at the field level. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B16: Firm-Level Parameters Calibrated to Sanctioned Russian Fields

Parameter	Symbol	Value	Description
Market Conditions			
Oil price	p	78	Brent crude price/barrel in 2013 (US$)
Royalty rate	γ	0.1644	Russian avg. royalty rate
Field Characteristics			
Complexity	θ	62.00	FID breakeven cost
Cost curvature	ϕ	3.02	Production cost convexity
Financial Parameters			
Discount rate	r	0.0733	Russian 10-year bond rate in 2013
Reserve Creation			
E&D efficiency	A	2.04	Reserve creation efficiency
E&D curvature	β	0.603	Diminishing returns to investment
Cost curvature	κ	1.5	E&D cost convexity
Sanction Intensities			
Technology wedge	τ^x	0.14	Input sanction tax
Financial premium	Δr_c	0.037	Firm-specific borrowing premium
MNC attenuation	m	0.35	Joint venture attenuation

Table B17: Sanction Impact Calibration

	Empirical Target	Model
Panel A: Sanction Impact		
Production (% change)	+2.8	+2.6
E&D Investment (% change)	-15.0	-22.2
Panel B: MNC Exit Impact		
Production (% change)	+1.9	+0.6
E&D Investment (% change)	-1.5	-4.8

Notes: Panel A shows sanction effects comparing Tech & Financial scenario to baseline. Panel B shows incremental MNC exit effects comparing forced MNC exit to MNC participation under sanctions. Empirical targets from event study (Panel A) and MNC equity share analysis at mean post-sanction share of 12.5% (Panel B).

Table B18: Sanction Impacts on Oil Production Over 20-Year Horizon

Scenario	E&D Investment (Million USD)	Time to Abandonment (Years)	Cumulative Production (Million BOE)	Cumulative Gov't Revenues (Million USD)
Panel A: Absolute Values				
Baseline	2,353.3	20.3	75,752.2	971,385.1
Tech Sanctions	2,286.2	20.2	75,483.0	967,933.8
Financial Sanctions	1,877.6	16.6	73,443.7	941,782.8
Tech & Financial	1,830.5	16.6	73,214.4	938,842.9
Tech & Financial with MNC Exit	1,742.7	16.5	73,088.3	937,225.9
Panel B: Change from Baseline				
Tech Sanctions	-67.1	-0.1	-269.1	-3,451.3
Financial Sanctions	-475.6	-3.7	-2,308.5	-29,602.3
Tech & Financial	-522.7	-3.7	-2,537.8	-32,542.2
Tech & Financial with MNC Exit	-610.6	-3.8	-2,663.9	-34,159.2
Panel C: % Change from Baseline				
Tech Sanctions	-2.9%	-0.3%	-0.4%	-0.4%
Financial Sanctions	-20.2%	-18.2%	-3.0%	-3.0%
Tech & Financial	-22.2%	-18.4%	-3.4%	-3.4%
Tech & Financial with MNC Exit	-25.9%	-18.6%	-3.5%	-3.5%

Notes: This table reports simulated impacts of sanctions on a representative 400-field portfolio calibrated to 2013 data from sanctioned Russian oil companies over a 20-year horizon. Panel A shows absolute values for each scenario. Panel B shows absolute changes from baseline. Panel C shows percentage changes from baseline. Technology sanctions restrict access to advanced oilfield equipment and expertise. Financial sanctions increase the cost of capital by blocking access to international financial markets. MNC exit refers to a counterfactual policy forcing multinational companies to exit joint ventures in sanctioned fields. All monetary values in millions of 2017 USD.

Table B19: 20-Year Sanction Impacts with Gradual Sanction Decay

Scenario	E&D Investment (Million USD)	Time to Abandonment (Years)	Cumulative Production (Million BOE)	Cumulative Gov't Revenues (Million USD)
Panel A: Absolute Values				
Baseline	2,353.3	20.3	75,752.2	971,385.1
Tech & Fin.	1,830.5	16.6	73,214.4	938,842.9
Tech & Fin. (Decay)	1,830.5	16.6	74,861.9	959,969.1
Panel B: Change from Baseline				
Tech & Fin.	-522.7	-3.7	-2,537.8	-32,542.2
Tech & Fin. (Decay)	-522.7	-3.7	-890.3	-11,416.0
Panel C: % Change from Baseline				
Tech & Fin.	-22.2%	-18.4%	-3.4%	-3.4%
Tech & Fin. (Decay)	-22.2%	-18.4%	-1.2%	-1.2%

Notes: Panel A shows absolute values over 20-year simulation horizon. Panel B shows changes from baseline. Panel C shows percentage changes from baseline. The decay scenario models gradual sanction weakening as firms develop alternative suppliers and financing. Technology sanctions (E&D cost wedge) decay linearly from initial intensity to zero over 20 years: $\tau(t) = \tau_0 \times (1 - 0.05t)$. Financial sanctions (discount rate premium) decay by half over 20 years: $\Delta r(t) = \Delta r_0 \times (1 - 0.025t)$. Simulated portfolio of 100 fields calibrated to 2013 data from sanctioned Russian oil companies.

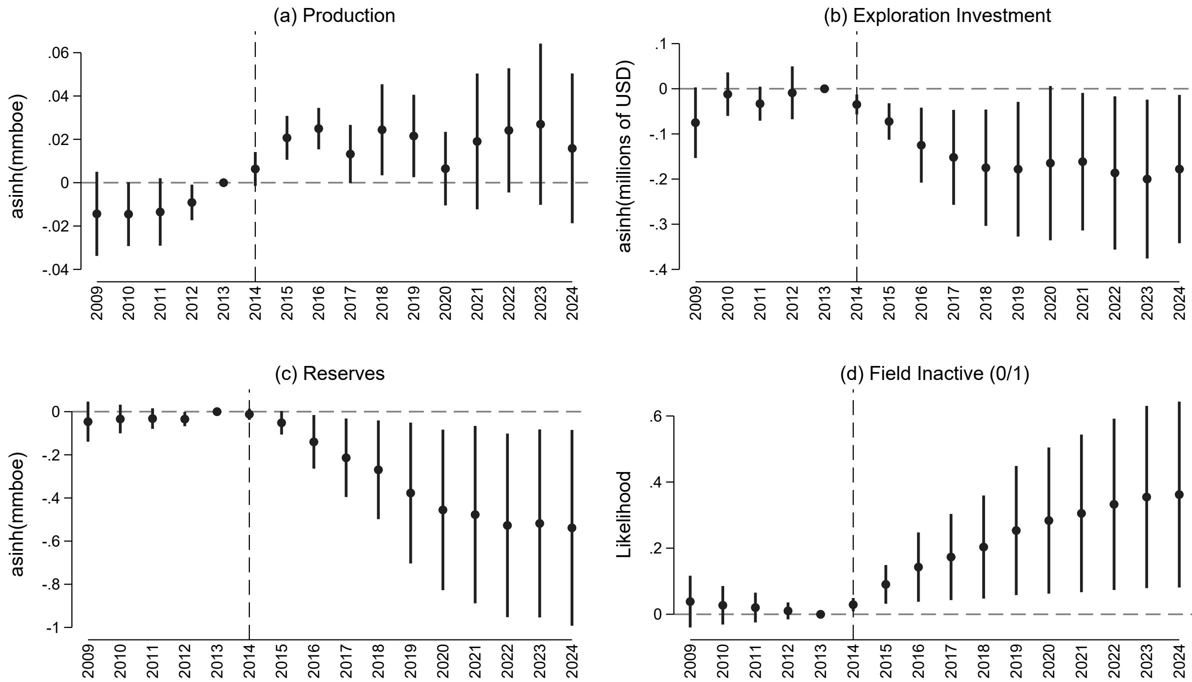
Table B20: 20-Year Sanction Impacts with US$60 Price Cap

Scenario	E&D Investment (Million USD)	Time to Abandonment (Years)	Cumulative Production (Million BOE)	Cumulative Gov't Revenues (Million USD)
Panel A: Absolute Values				
Baseline	2,353.3	20.3	75,752.2	971,385.1
Price Cap Only	1,499.6	21.2	69,249.9	683,080.7
Tech & Fin.	1,830.5	16.6	73,214.4	938,842.9
Tech & Fin. + Price Cap	1,171.8	17.7	66,936.5	660,262.0
Panel B: Change from Baseline				
Price Cap Only	-853.7	0.9	-6,502.3	-288,304.4
Tech & Fin.	-522.7	-3.7	-2,537.8	-32,542.2
Tech & Fin. + Price Cap	-1,181.4	-2.6	-8,815.6	-311,123.1
Panel C: % Change from Baseline				
Price Cap Only	-36.3%	4.4%	-8.6%	-29.7%
Tech & Fin.	-22.2%	-18.4%	-3.4%	-3.4%
Tech & Fin. + Price Cap	-50.2%	-12.7%	-11.6%	-32.0%

Notes: Panel A shows absolute values over 20-year simulation horizon. Panel B shows changes from baseline. Panel C shows percentage changes from baseline. The price cap scenario imposes a $60/barrel ceiling on Russian oil sales in addition to technology and financial sanctions. This represents a 23% reduction from the baseline model price of $78/barrel (2013 average Brent crude). Simulated portfolio of 100 fields calibrated to 2013 data from sanctioned Russian oil companies.

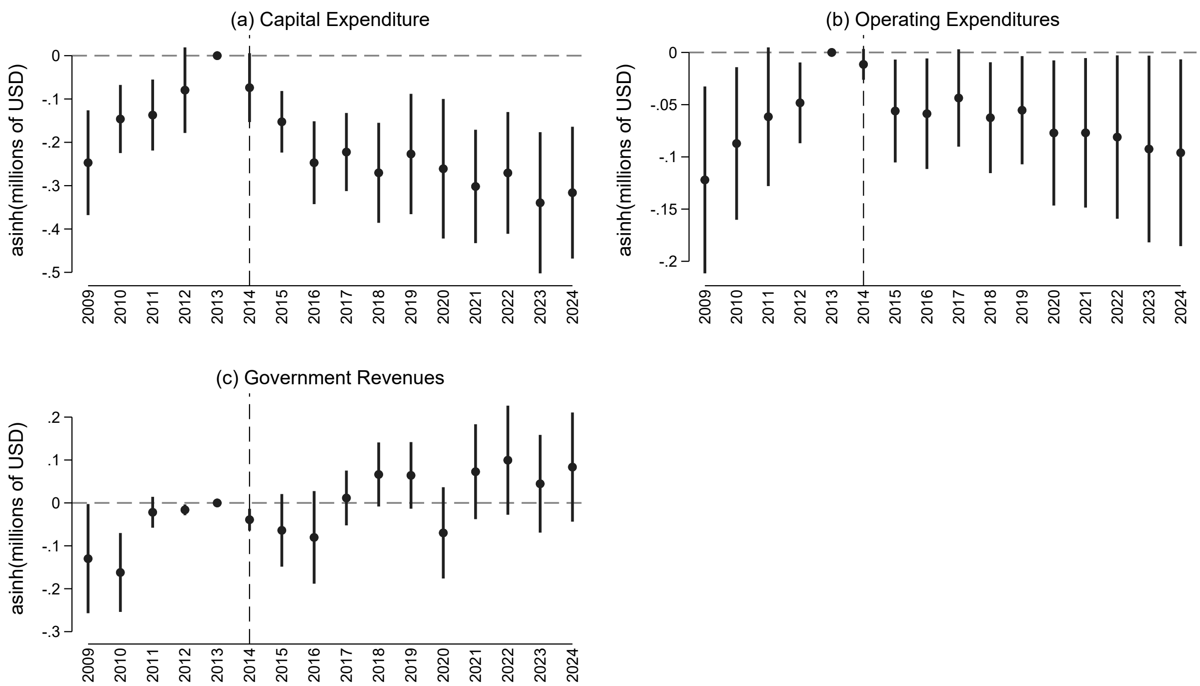
C Robustness Checks

Figure C1: Sanction Impacts on Field-Level Outcomes (Broader Treatment Definition: Sanctioned Firms and Subsidiaries)



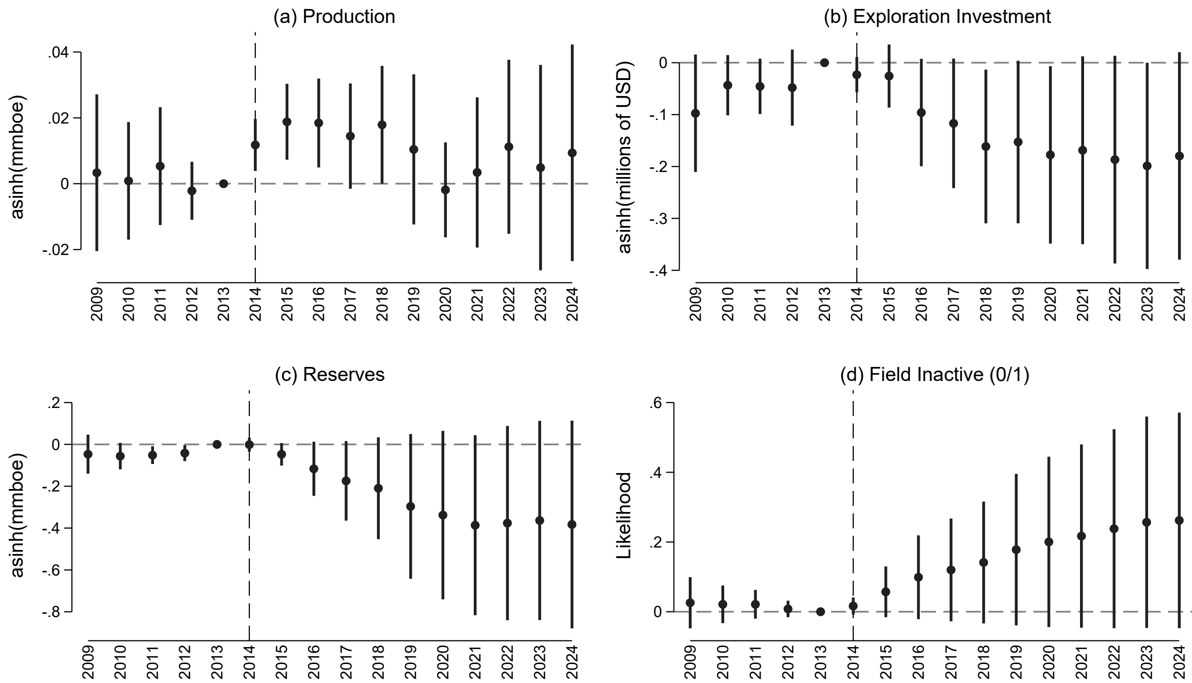
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). This alternative, broader treatment definition also includes fields with participation by level-1 beneficial subsidiaries of sanctioned companies. Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

Figure C2: Sanction Impacts on Additional Field-Level Outcomes (Broader Treatment Definition: Sanctioned Firms and Subsidiaries)



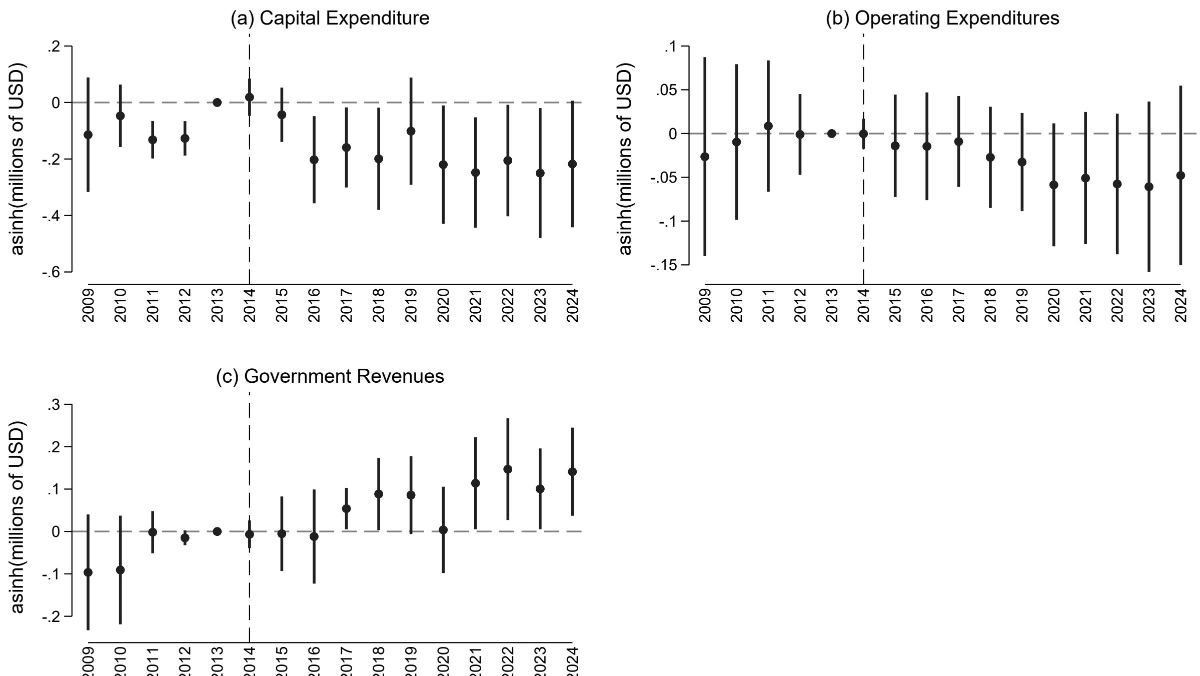
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). This alternative, broader treatment definition also includes fields with participation by level-1 beneficial subsidiaries of sanctioned companies. Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes.

Figure C3: Sanction Impacts on Field-Level Outcomes (Narrower Treatment Definition: Sanctioned Majority Stakeholders)



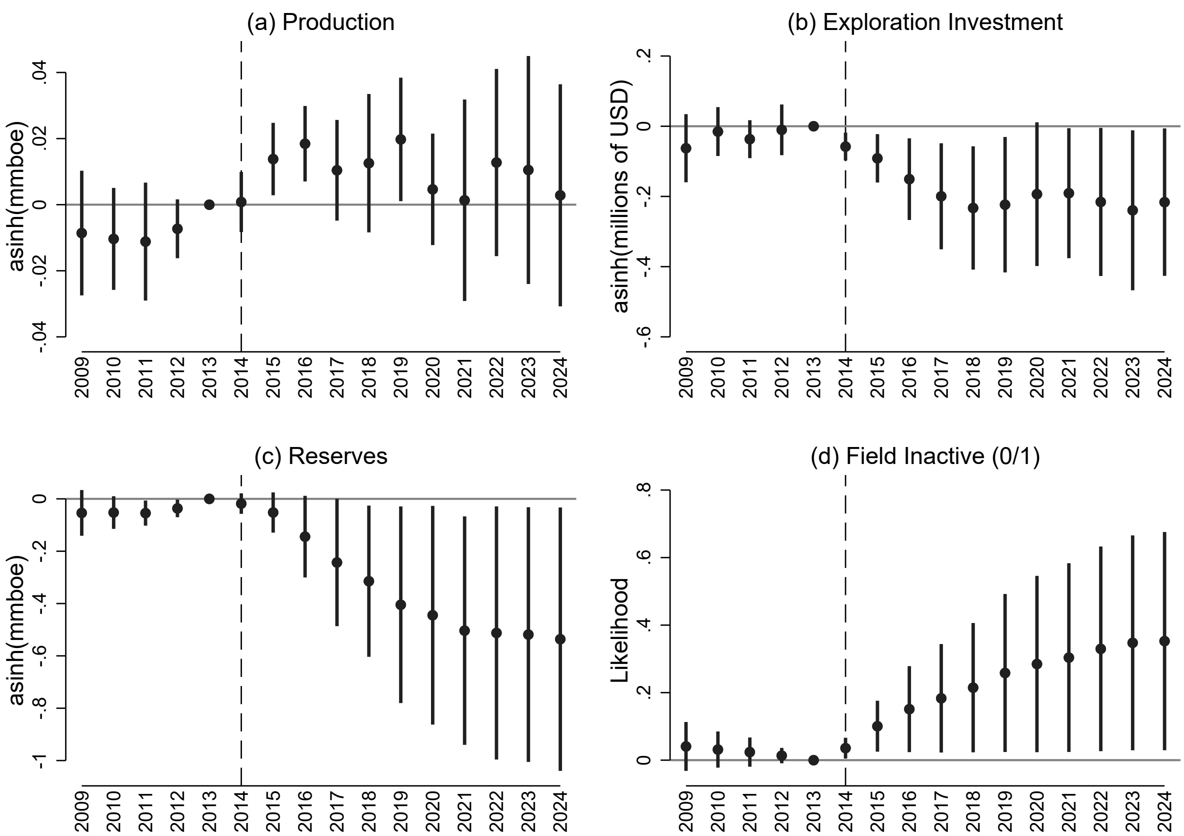
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). This alternative, narrower treatment definition, restricts treated fields to those with majority participation by sanctioned companies in 2013, thus excluding from the treated group fields where sanctioned companies controlled less than 50% stakes. Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

Figure C4: Sanction Impacts on Additional Field-Level Outcomes (Narrower Treatment Definition: Sanctioned Majority Stakeholders)



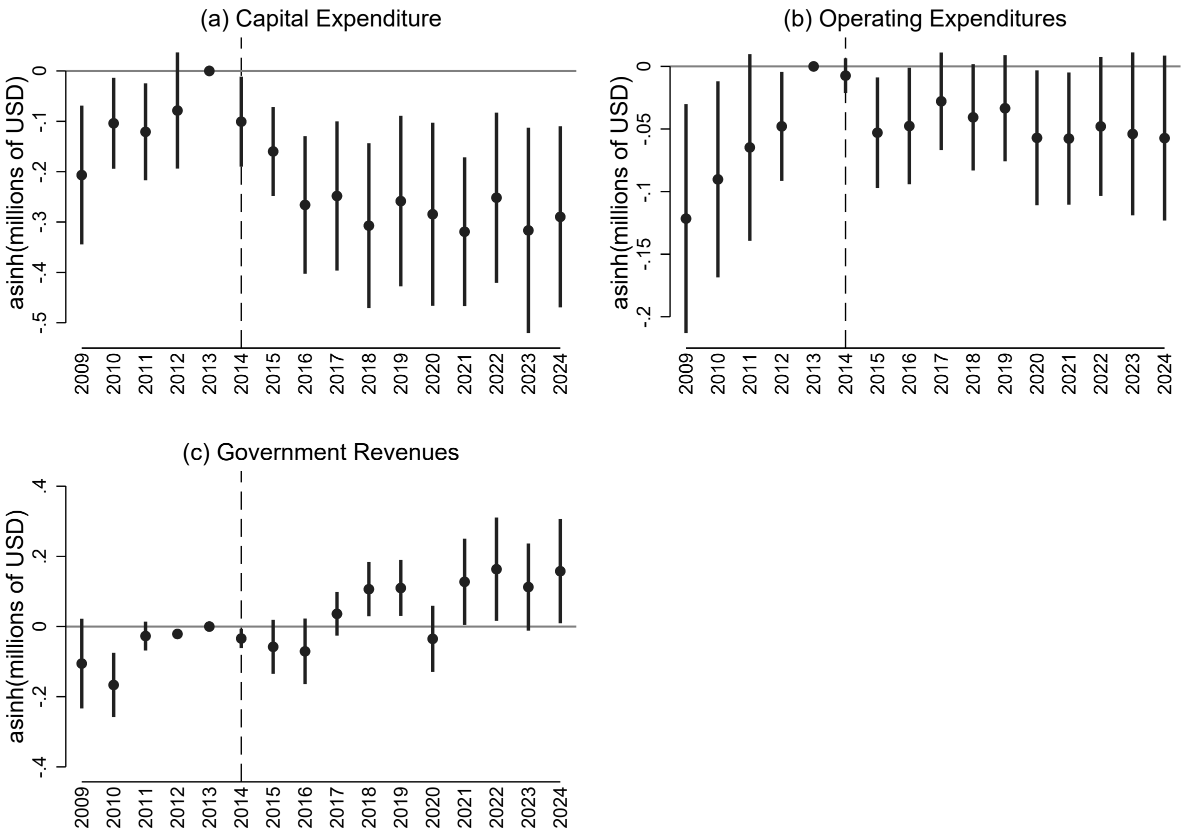
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). This alternative, narrower treatment definition, restricts treated fields to those with majority participation by sanctioned companies in 2013, thus excluding from the treated group fields where sanctioned companies controlled less than 50% stakes. Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes.

Figure C5: Sanction Impacts on Field-Level Outcomes (CEM Matching)



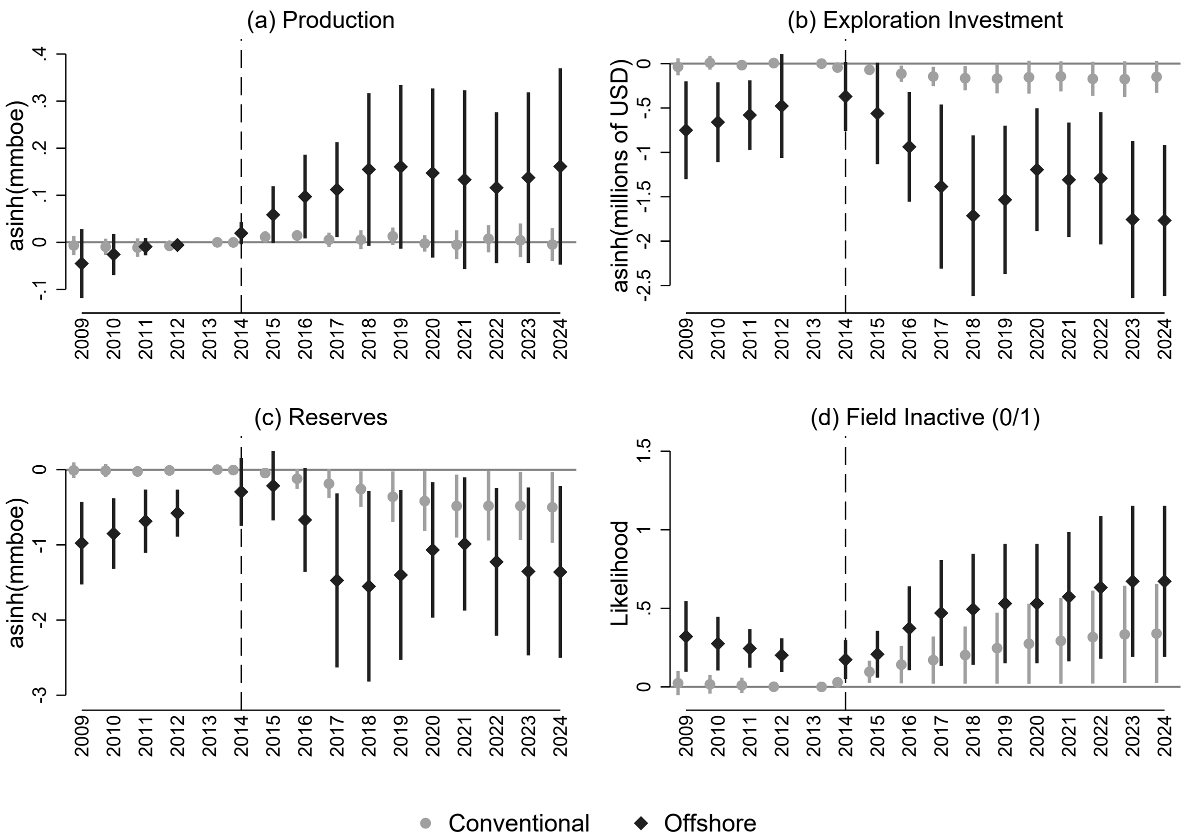
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C6: Sanction Impacts on Additional Field-Level Outcomes (CEM Matching)



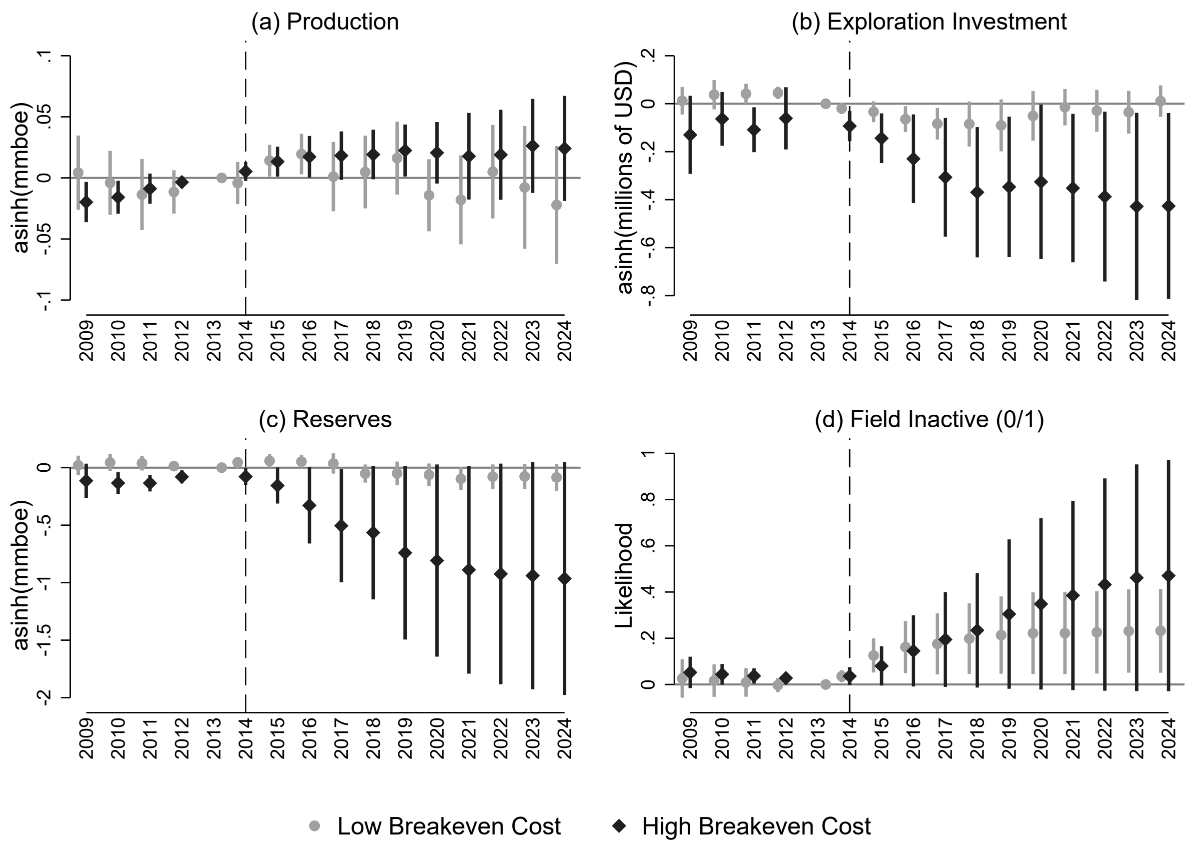
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes are transformed using the inverse hyperbolic sine transformation to accommodate zero values, and are measured in millions of constant 2017 USD. Government revenues are the sum of royalties, profit oil, and other field-specific taxes. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C7: Sanction Impacts on Field-Level Outcomes, by Segment (CEM Matching)



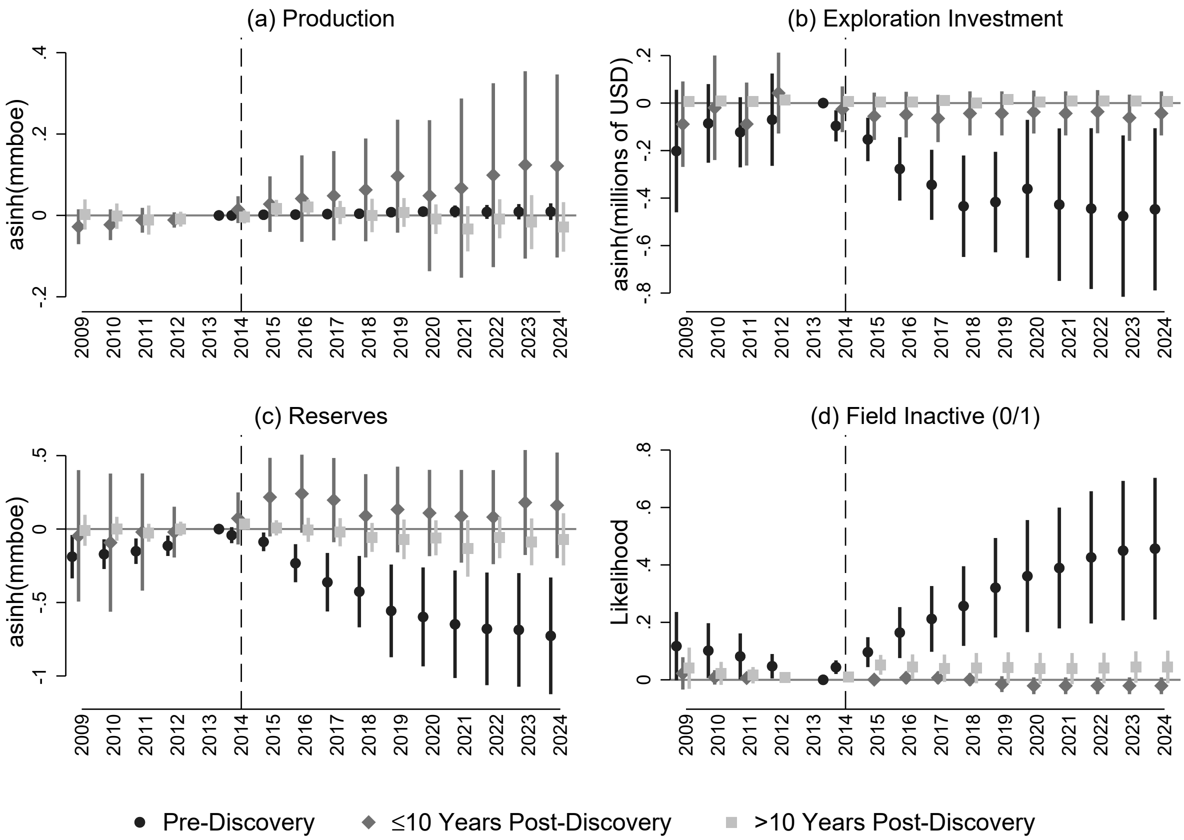
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Event studies are estimated separately for conventional onshore and offshore fields. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C8: Sanction Impacts on Field-Level Outcomes, by Breakeven Price (CEM Matching)



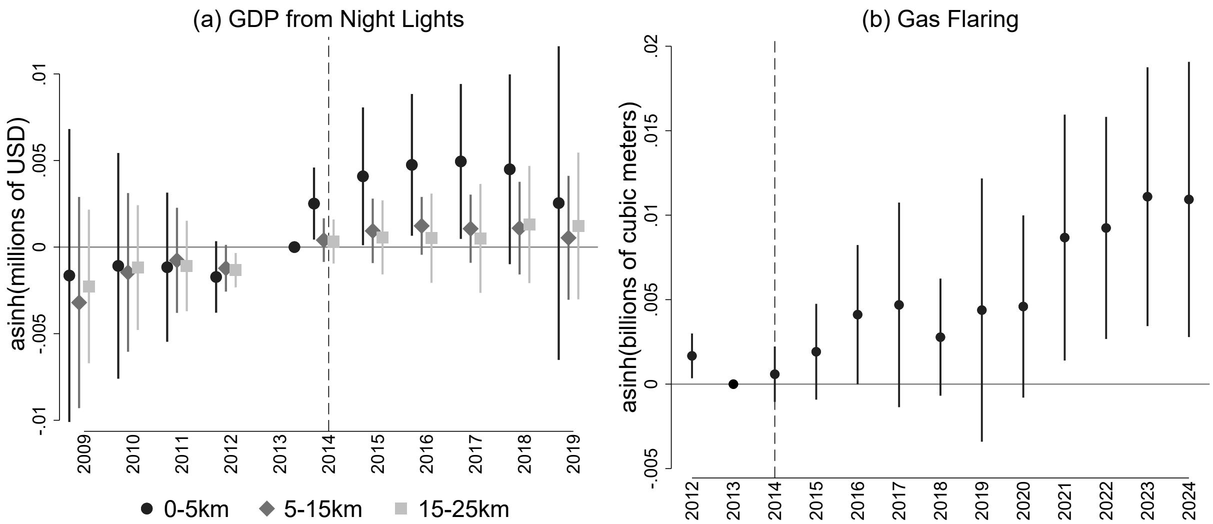
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Event studies are estimated separately for fields with below median (low cost) and above median (high cost) FID breakeven prices at the time of discovery, which constitute a best guess of the field's technical complexity and cost of production. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C9: Sanction Impacts on Field-Level Outcomes, by Field Age (CEM Matching)



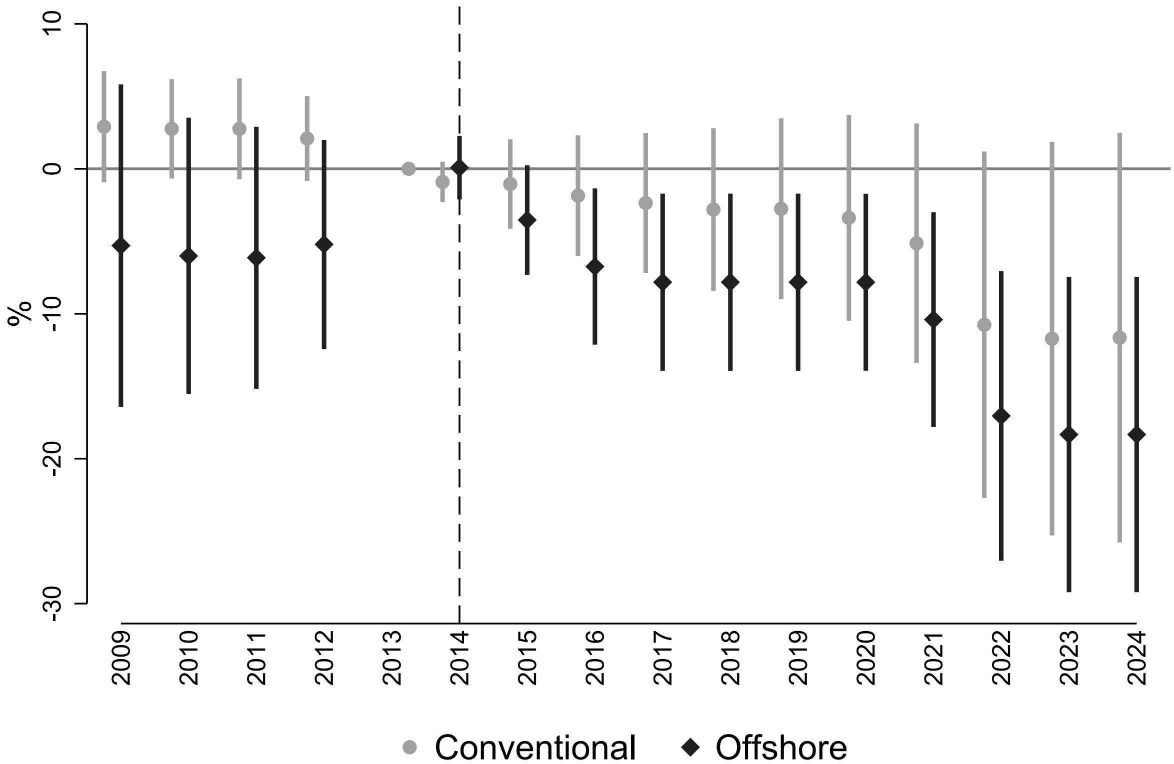
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Event studies are estimated separately for fields based on their status in 2013: unexplored (pre-discovery), recent (up to 10 years post-discovery), and mature (more than 10 years post-discovery). The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C10: Sanction Impacts on Field-Level Geospatial Outcomes (CEM Matching)



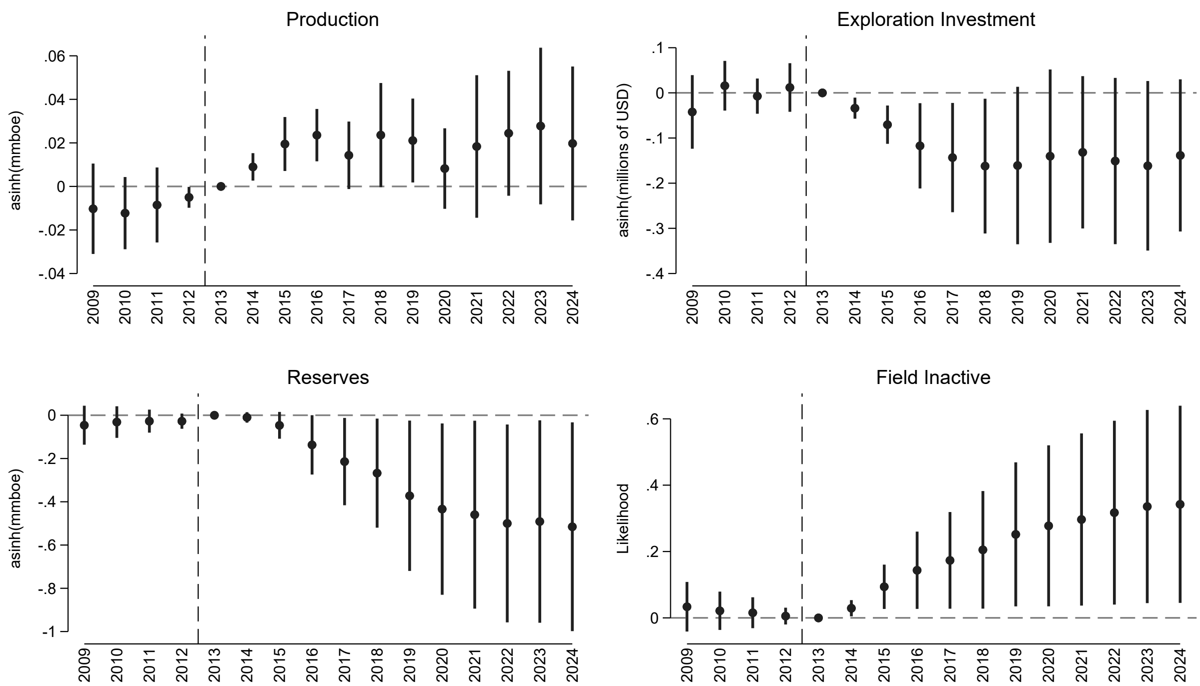
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcomes are transformed using the inverse hyperbolic sine function. GDP (in millions of USD, from Chen et al. (2022)) is summed across all 1x1km pixels within varying distance radii from oil field centroids. Distance bins are mutually exclusive, such that the first sums night-light-imputed GDP between 0-5km from field centroids, while the second sums GDP between 5-15km (excluding the 0-5km GDP) and the third sums GDP between 15-25km (excluding the 0-15km GDP). Gas flaring (in billions of cubic meters, from Payne Institute for Public Policy (2024)) is summed across all flaring point sources within exact oil field boundaries. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C11: Sanction Impacts on Multinational Participation, by Segment (CEM Matched)



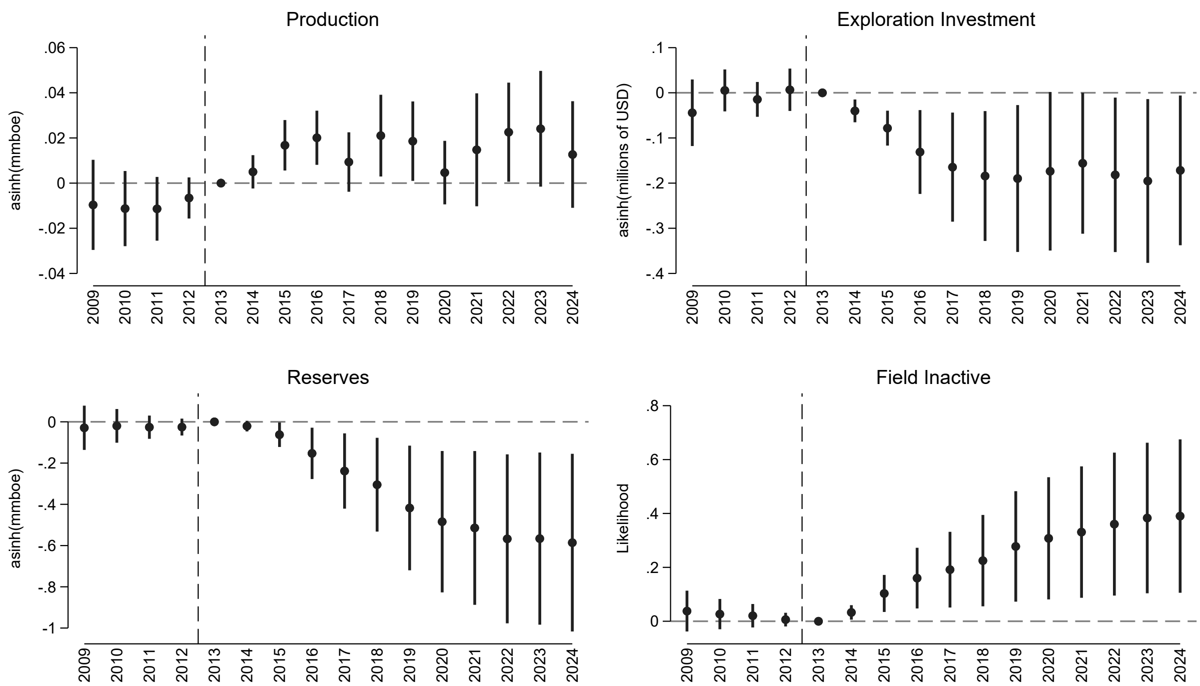
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcome is defined as the percentage of a field's ownership held by countries headquartered outside of Russia. Event studies are estimated separately for conventional onshore and offshore fields. The sample is restricted to treated and control fields that exactly match on province, onshore/offshore segment, and quintiles of pre-treatment (2010-2013) levels of production, exploration investment, government payments, and reserves. Coarsened exact matching weights are included in the regressions.

Figure C12: Sanction Impacts on Field-Level Outcomes, with Sub-Basin-Year Fixed Effects



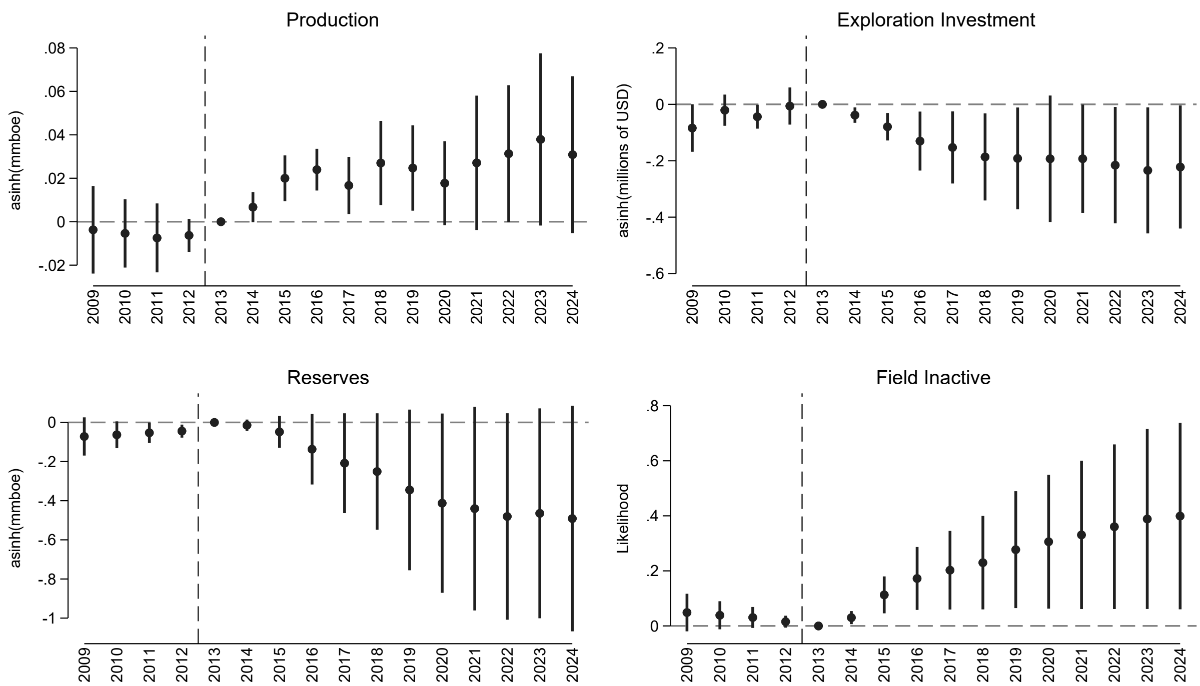
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated using OLS. Specifications include field and year fixed effects, as well as additional sub-basin-by-year fixed effects to absorb time trends at the level of localized geological formations (i.e., correlated spatial shocks or technology changes affecting specific geological profiles or production clusters). Standard errors are clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

Figure C13: Sanction Impacts on Field-Level Outcomes, with Oblast-Year Fixed Effects



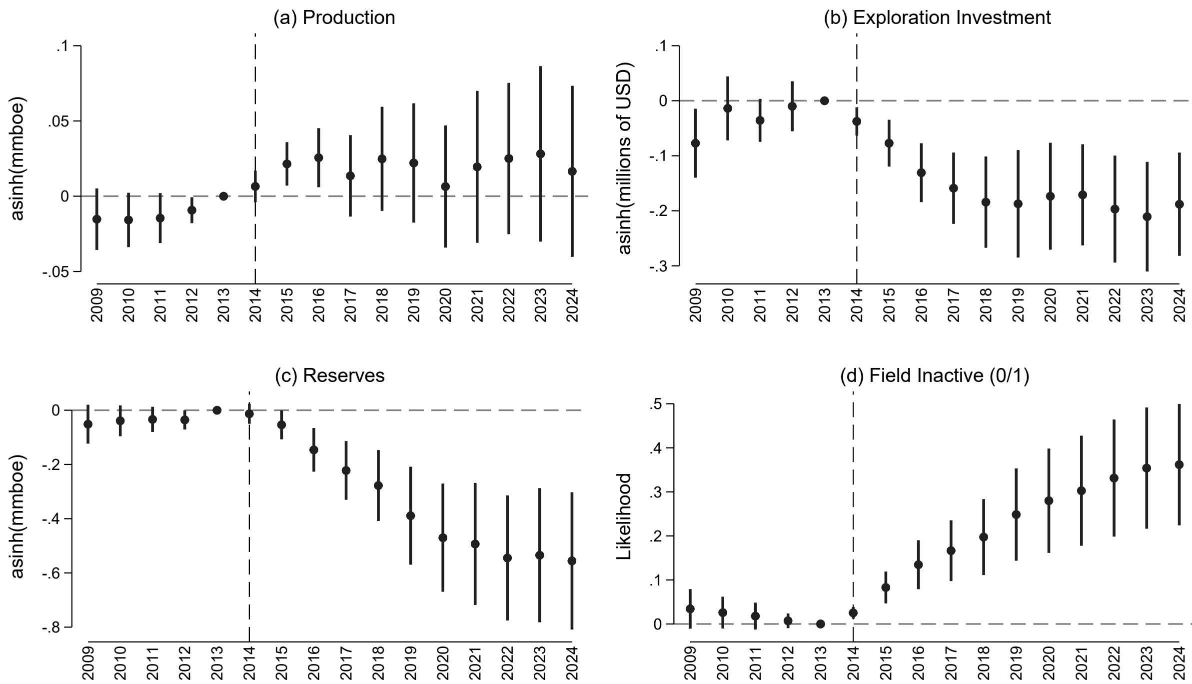
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated using OLS. Specifications include field and year fixed effects, as well as additional oblast-by-year fixed effects to absorb time trends at the state level (i.e., local policy changes). Standard errors are clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

Figure C14: Sanction Impacts on Field-Level Outcomes, with Breakeven-Cost-Decile-by-Year Fixed Effects



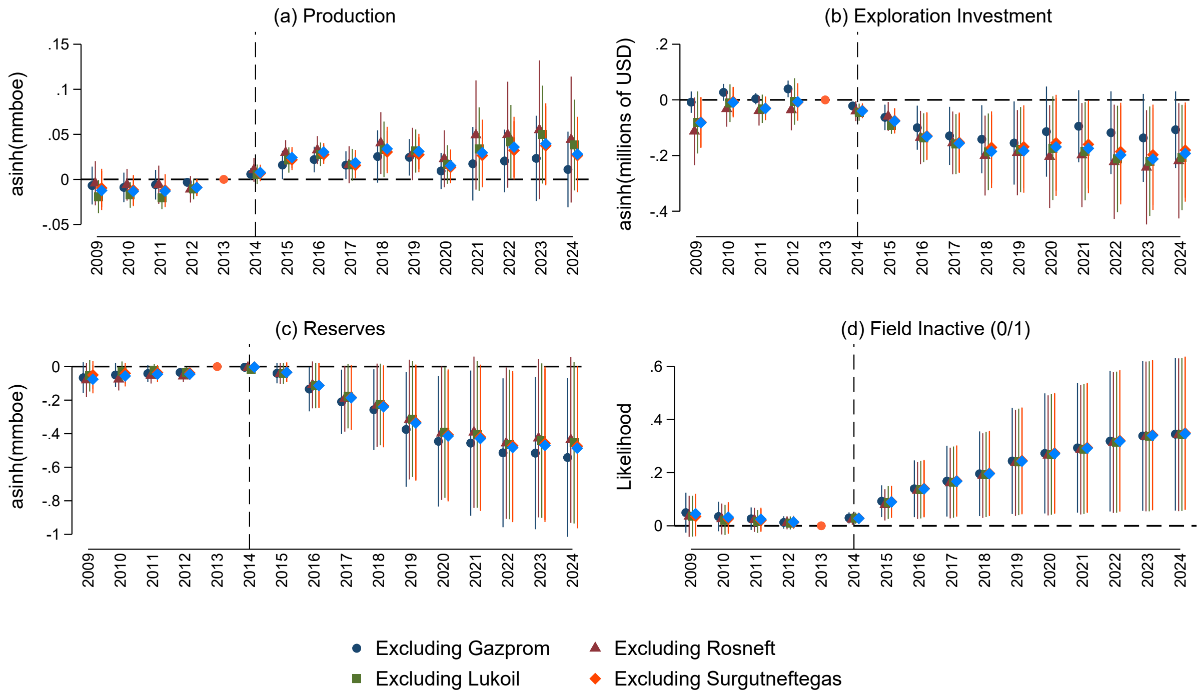
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated using OLS. Specifications include field and year fixed effects, as well as breakeven-cost-decile-by-year fixed effects, which absorb differential time trends across the field cost distribution including differential exposure to the 2014–2016 oil price decline. Standard errors are clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year.

Figure C15: Sanction Impacts on Field-Level Outcomes, Excluding Ukraine Border Regions



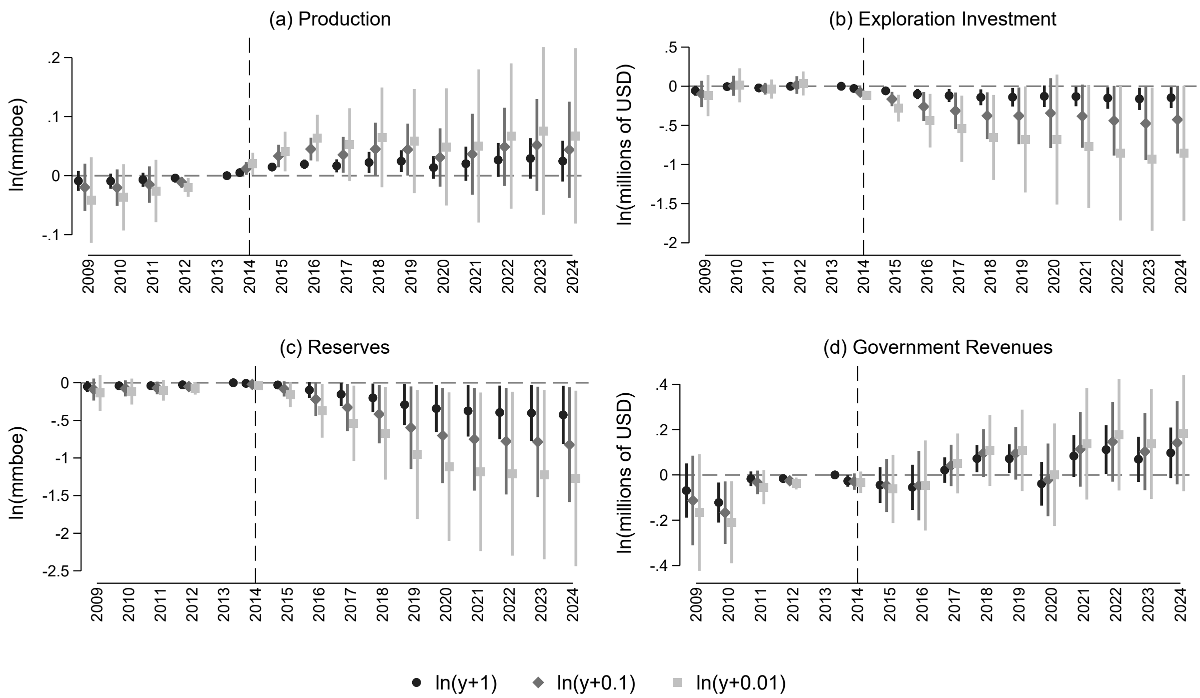
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects. Standard errors are clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Russian states (oblasts) bordering Ukraine (Bryansk, Kursk, Belgorod, Voronezh, Rostov, and Krasnodar) are omitted to avoid potential confounding effects from direct impacts of the 2014 or 2022 conflicts.

Figure C16: Leave-One-Company-Out Sensitivity Analysis



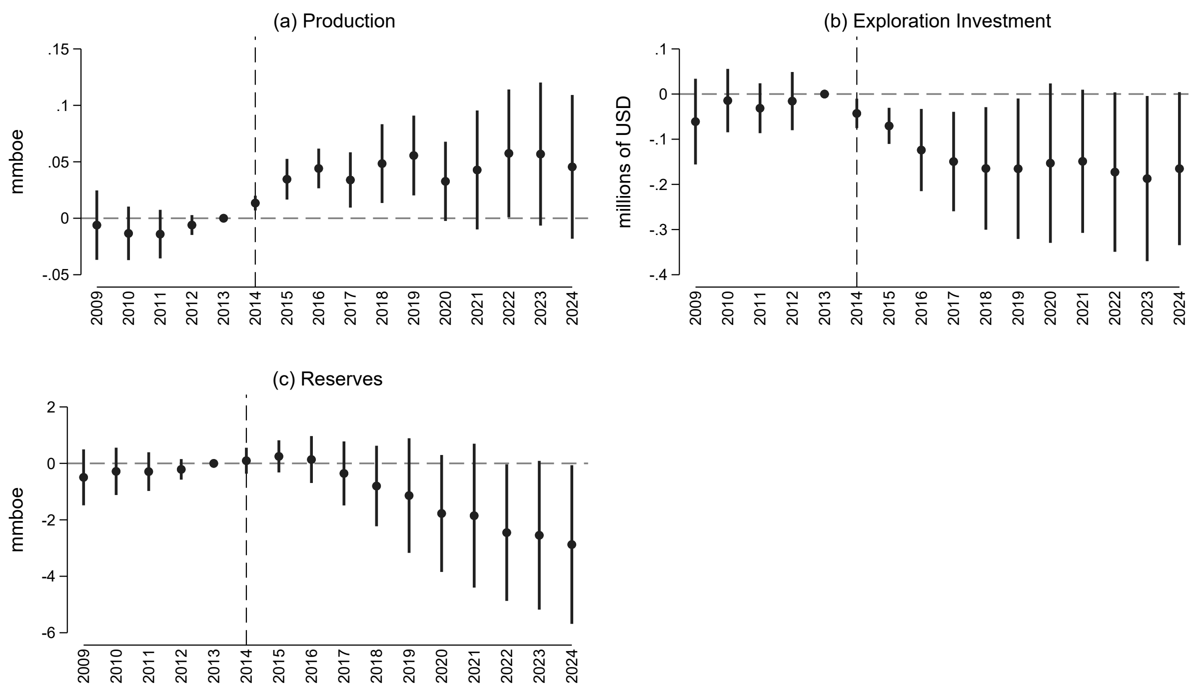
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. All outcomes (except d) are transformed using the inverse hyperbolic sine transformation to accommodate zero values. Production (a) and reserves (c) are measured in millions of barrels of oil equivalent. Exploration investment is in millions of constant 2017 USD. Field inactivity (d) is a 0/1 indicator of whether any company is listed as the owner of a field in a given year. Specifications are re-estimated four times, each time excluding fields held in 2013 by one of the four sanctioned companies from the sample (considering Gazprom and Gazprom Neft one entity). The objective of this exercise is to assess sensitivity of main results to specific companies.

Figure C17: Alternative Log-Transformations Sensitivity Analysis



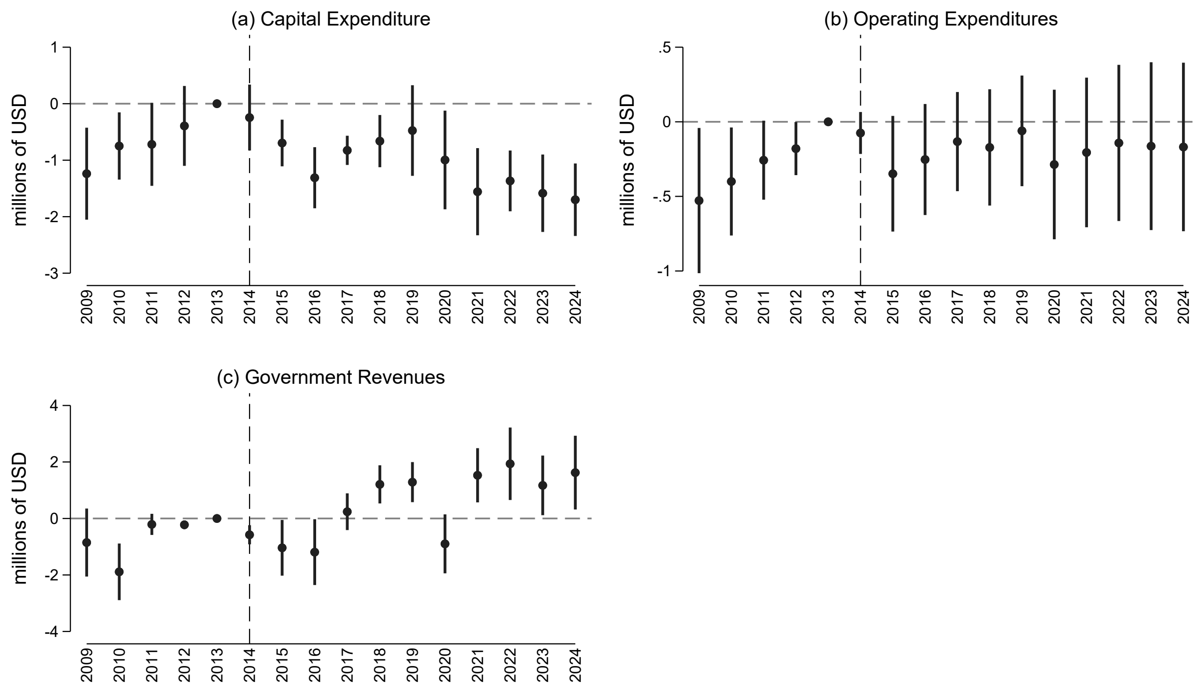
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Because the outcome variable contains zeros, log transformations must take the form $\ln(y+c)$, rather than $\ln(y)$, to avoid introducing missing values and selection-into-sample concerns. Estimates are reported for three values of c (1, 0.1, and 0.01) to assess sensitivity to this arbitrary choice of constant.

Figure C18: Sanction Impacts on Field-Level Outcomes with Untransformed Outcomes



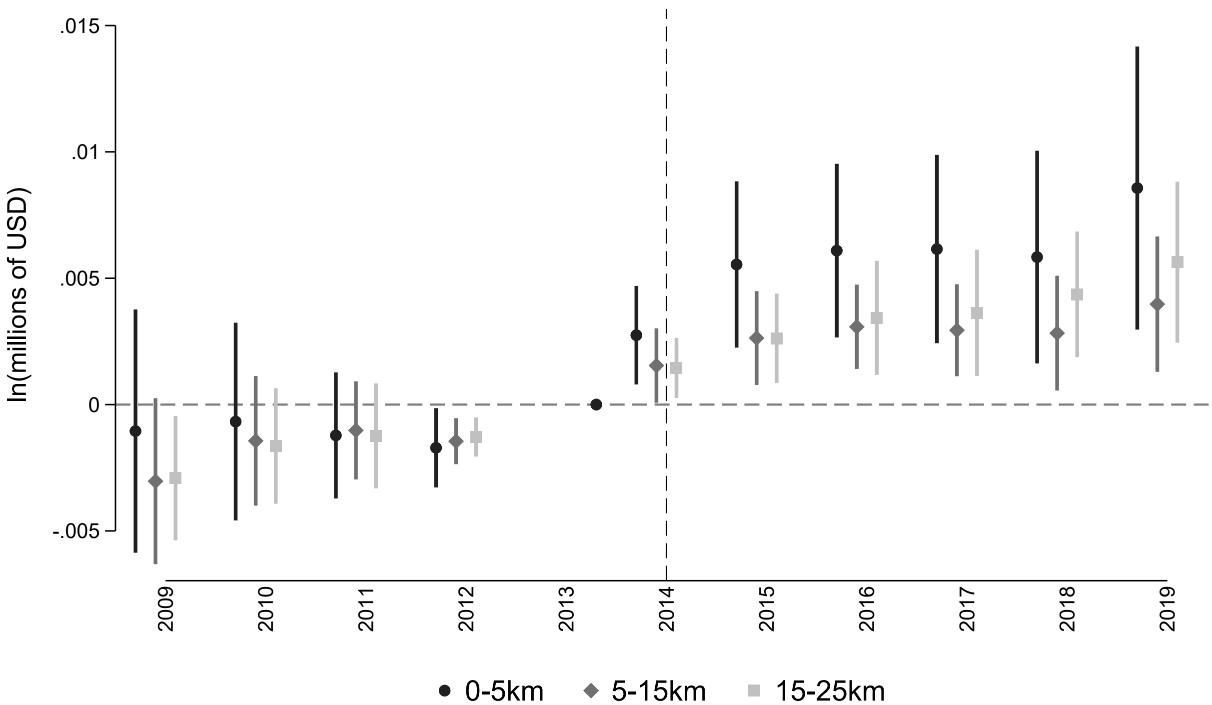
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcomes are untransformed.

Figure C19: Sanction Impacts on Additional Field-Level Outcomes with Untransformed Outcomes



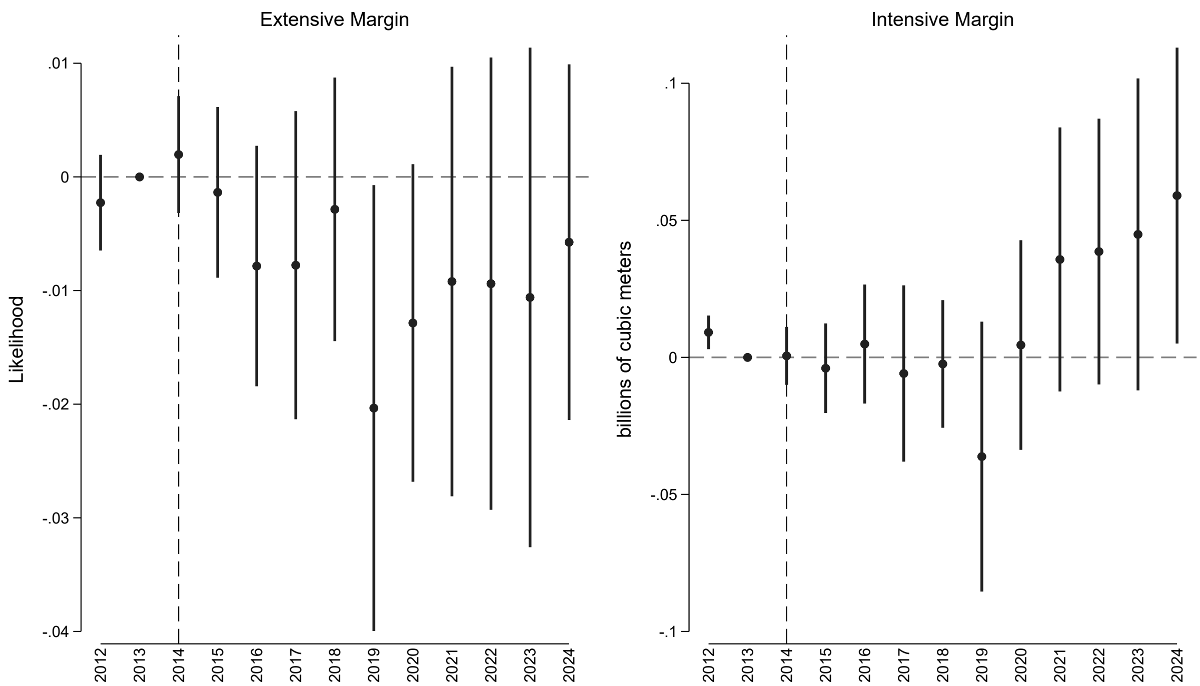
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcomes are untransformed.

Figure C20: Sanction Impacts on Night-Light GDP, ln(y) transformation



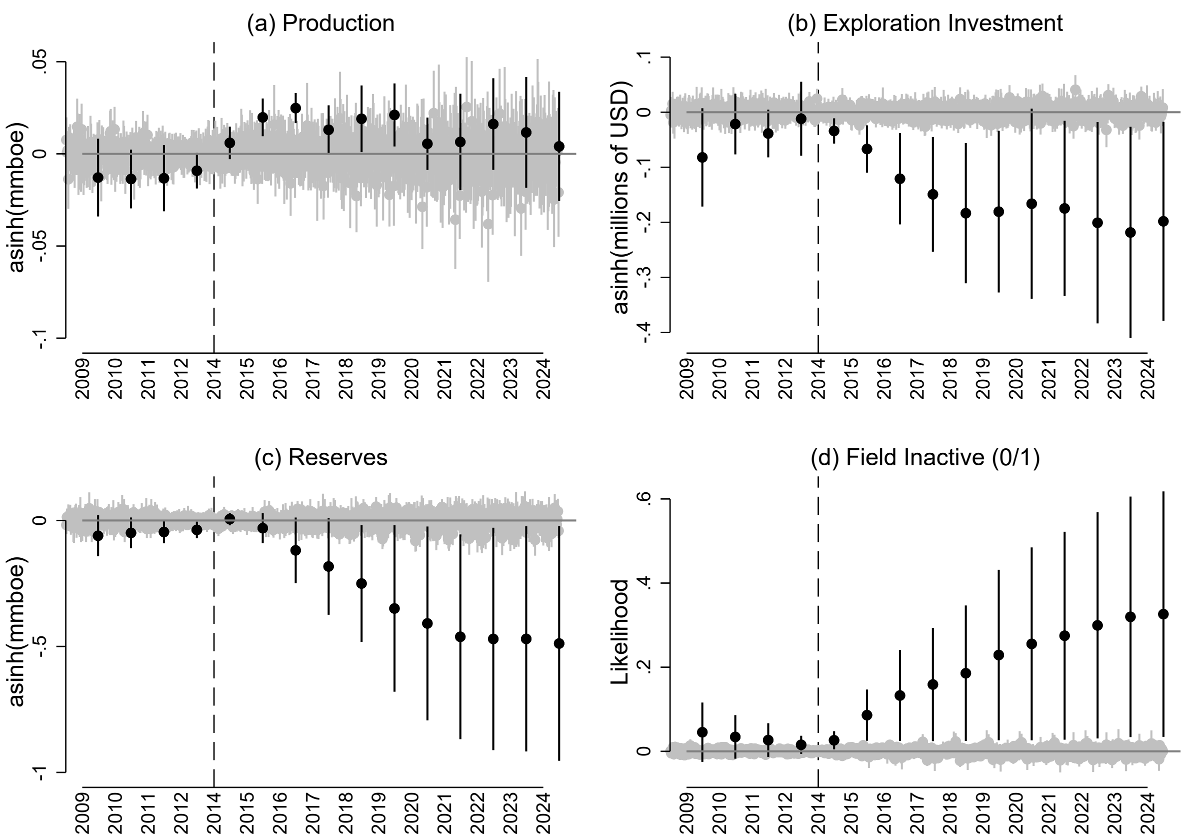
Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Outcomes are transformed using the natural log function. GDP (in millions of USD) is summed across all 1x1km pixels within varying distance radii from oil field centroids. Distance bins are mutually exclusive.

Figure C21: Sanction Impacts on Gas Flaring (Extensive and Intensive Margins)



Note: Figure reports coefficient estimates with 95% confidence intervals in years before and after sanctions were imposed in 2014. The omitted base year is 2013. Event studies compare fields operated by sanctioned versus non-sanctioned companies as of 2013, estimated following Callaway and Sant'Anna (2021). Specifications include field and year fixed effects, with standard errors clustered by 2013 operating company, and are estimated on a balanced field-year panel. Gas flaring (in billions of cubic meters) is summed across all flaring point sources within exact oil field boundaries. The left panel reports estimated sanction impacts on the extensive margin of flaring, i.e., a 0/1 indicator of whether any flaring is present. The right panel reports estimated impacts on the intensive margin of flaring, i.e., volume flared in the sub-sample where positive flaring is occurring.

Figure C22: Placebo Tests



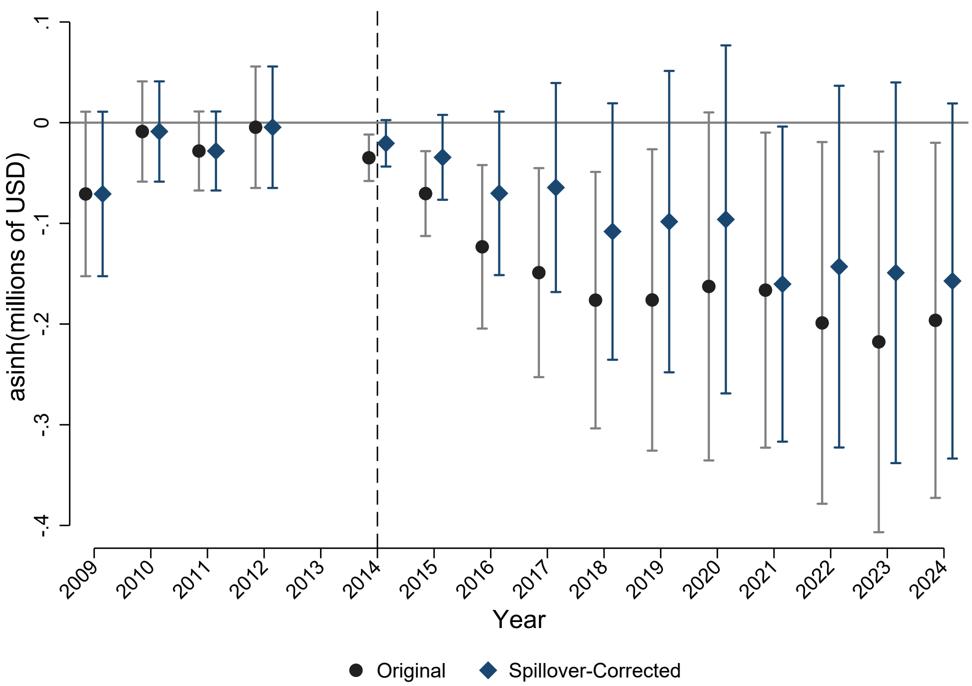
Note: Figure reports event study estimates that are reported and described in Figure 4, overlaid on top of 100 placebo event studies. These are estimated by randomly allocating treatment status across the full sample in proportion to the real treated share of fields, and estimating event studies for each of these placebo treatments.

Table C1: Randomization Inference: Permutation P-values

	Exploration asinh(mill. USD)		Production asinh(mmboe)		Reserves asinh(mmboe)		Field Inactive Likelihood	
Year	Coef.	P-val	Coef.	P-val	Coef.	P-val	Coef.	P-val
2014	-0.035	<0.01	0.007	0.10	-0.006	0.58	0.028	<0.01
2015	-0.070	<0.01	0.022	<0.01	-0.038	0.01	0.088	<0.01
2016	-0.123	<0.01	0.028	<0.01	-0.119	<0.01	0.138	<0.01
2017	-0.149	<0.01	0.017	0.03	-0.191	<0.01	0.166	<0.01
2018	-0.176	<0.01	0.031	<0.01	-0.242	<0.01	0.194	<0.01
2019	-0.176	<0.01	0.028	<0.01	-0.340	<0.01	0.242	<0.01
2020	-0.163	<0.01	0.014	0.13	-0.415	<0.01	0.270	<0.01
2021	-0.166	<0.01	0.027	0.02	-0.432	<0.01	0.291	<0.01
2022	-0.199	<0.01	0.033	0.01	-0.482	<0.01	0.317	<0.01
2023	-0.218	<0.01	0.036	<0.01	-0.469	<0.01	0.339	<0.01
2024	-0.196	<0.01	0.026	0.04	-0.486	<0.01	0.345	<0.01
Sig. at $p < 0.01$	11/11		5/11		9/11		11/11	
Sig. at $p < 0.05$	11/11		9/11		10/11		11/11	

Notes: Table reports coefficient estimates and permutation p-values from randomization inference. P-values are computed as the share of 100 placebo estimates (constructed by randomly reassigning treatment status while holding the number of treated units fixed) that exceed the real estimate in absolute value. The minimum reportable p-value with 100 draws is 0.01, reported as <0.01. All specifications follow Callaway and Sant'Anna (2021) with field and year fixed effects and standard errors clustered by 2013 operating company.

Figure C23: Spillover-Corrected Effects on Exploration Investment



Note: Figure reports event study estimates for exploration investment (in millions of USD), transformed using the inverse hyperbolic sine function, as described in Figure 4. The "Original" estimates are the standard event study coefficients, while "Spillover-Corrected" estimates adjust for potential capital reallocation from sanctioned to non-sanctioned fields. For each post-2014 year, the spillover correction is calculated as the control group's deviation from its pre-2014 linear trend (estimated using 2009-2013 data), which is then added to the original event study coefficient to obtain the spillover-corrected estimate, which represents the treatment effect that would have been observed absent capital reallocation if the entire increase in control group exploration is attributable to sanctioned-induced spillovers. Confidence intervals are based on the original standard errors and do not account for uncertainty in the spillover estimation.