INSTITUTIONS AND THE LOCATION OF OIL EXPLORATION

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Abstract
We provide evidence that institutions have a strong influence over where oil and gas exploration takes place. We utilise a global data set on the location of exploration wells and national borders. This allows for a regression discontinuity design with the identifying assumption that the position of borders was determined independently of geology. In order to break potential simultaneity between borders, institutions, and activities in the oil sector, we focus on drilling that occurred after the formation of borders and institutions. Our sample covers 88 countries over the 1966–2010 period. At borders, we estimate more than twice as much drilling on the side with better institutional quality. Subsample analyses reveal effects of institutions on exploration drilling in both developing and high income countries, as well as across three types of operating companies. We find that the supermajor international oil companies are particularly sensitive to institutional quality in developing countries. Our findings are consistent with the view that institutions shape both exploration companies' incentives to invest in drilling and host countries' supply of drilling opportunities. (JEL: F21, O13, O43, Q32)

1. Introduction

Institutions, generally defined as "the rules of the game in a society" (North 1990), are considered to be a fundamental cause of economic growth. Aspects, such as

The editor in charge of this paper was Claudio Michelacci.

Acknowledgments: We thank four anonymous referees, the co-editor, Claudio Michelacci, and Jørgen Juel Andersen, Roland Hodler, Guy Michaels, Magne Mogstad, Klaus Mohn, Linda Nøstbakken, Rick van der Ploeg, Simon Quinn, Michael Ross, Shqiponja Telhaj, Ragnar Torvik, Tony Venables as well as seminar participants at NHH Bergen, University of Bergen, EUDN Berlin, RES Manchester, EGIT Munich, Norwegian Economist Meeting Oslo, ESOP-OxCarre workshop Oxford, University of Oxford, NRG Siegen, University of Stavanger, University of Stirling, NOITS Stockholm, and University of Sussex for useful comments. We also thank Wood Mackenzie for academic access to their PathFinder database. Support from the BP funded Centre for the Analysis of Resource Rich Economies (OxCarre) at the University of Oxford and the Equinor chair in economics at the Norwegian School of Economics is also appreciated.

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Journal of the European Economic Association 2019 00(0):1–30 DOI: 10.1093/jeea/jvz028

constraints on the executive or the rule of law, shape incentives to invest, and therefore growth trajectories (Acemoglu et al. 2005). However, identifying the causal effect of institutions on economic activity is challenging because of correlated factors and because institutional characteristics are themselves endogenous equilibrium outcomes (Acemoglu et al. 2005; Besley and Persson 2010).

This paper uses the setting of oil and gas exploration to estimate the causal effect of institutional quality on investment. We follow earlier work by Bohn and Deacon (2000) who examined the effect of expropriation risk on investments in oil exploration and production.[1] In their "demand" for drilling locations, investors take into account the probability of discovery and the net present value of a discovered barrel of oil. The former depends upon geology. The latter upon operational costs and risks, which are again partly determined by institutions. "Supply" of drilling locations, that is, potential host countries facilitate drilling through licensing and tax deductions for exploration costs, is also plausibly affected by institutional quality.[2] For these reasons, oil exploration is expected to vary with institutional quality for a given set of geological conditions. This paper argues that variation in institutional quality between countries can help explain the uneven distribution of investments and hence the distribution of known subsoil wealth between countries.[3]

The setting of oil exploration lends itself particularly well to a spatial regression discontinuity (RD) design, such as the one used by Michalopoulos and Papaioannou (2013) and earlier work by Black (1999). First, a global data set including the location of oil exploration wells and national borders allows us to examine investments in areas proximate to national borders. Second, the subsoil nature of oil reservoirs together with the timing of borders make the location of borders plausibly exogenous with respect to oil.[4] If these borders were determined independently of subsoil oil, a discontinuity in the number of wells at national borders can be interpreted as the causal effect of the border on oil exploration. We consider borders that have not changed since 1965 and only drilling that took place from 1966.

We find that, everything else equal, exploration companies chose to drill on the side of the border with better Freedom House Political Rights Index score in more than two out of three times. Scaled with actual differences in the Freedom House Political

1. We focus in this paper on oil and gas exploration, measured in the form of drilling of oil and gas exploration wells. We use "oil" as a short hand expression for "oil and gas".

2. Institutions may affect both demand for drilling by the exploration companies and supply of drilling opportunities by the host countries. In our setting, we observe only the equilibrium outcome and lack of excludable instruments for demand and supply prevents us from identifying their effects separately.

3. Aggregate figures show that almost 90% of oil investments have historically taken place in upper-middle and high income countries (McKinsey Global Institute 2013). Collier (2010) estimates that OECD countries have discovered about five times more subsoil natural resources per square km than those in Africa—130,000 USD per square km compared to 25,000.

4. In contrast, application of other measures of economic activity used in the literature, such as nighttime lights, is more vulnerable to the possibility that the location of people, firms, and political borders are simultaneously determined. Related issues are discussed by Alesina et al. (2011), Michalopoulos and Papaioannou (2013), Michalopoulos and Papaioannou (2014), and Turner et al. (2014).

Rights Index, our estimates imply that a gap of one standard deviation translates to 85% more wells. To put these magnitudes in perspective, a back-of-the-envelope calculation suggests that the average exploration well results in production of about 2500 barrels per day. Narrowing down our sample to 10 km from the borders, as an example, we observe about 2000 wells located on the worse governed side. An 85% increase would then add 1700 extra wells, which would yield 4.25 million barrels per day, or about 4.9% of the global daily production in 2013.[5] We interpret our estimates to be close to long-run estimates, as they are based on accumulated drilling over the period 1966 to 2010.

To scrutinize the key identifying assumption that national borders are randomly assigned with respect to the underlying geology, we restrict our sample in three ways. First, we limit our sample to borders that have been stable since 1946, instead of 1965 in our main sample. Then we exclude borders between two states with recorded military conflicts, to address the concern that oil exploration, conflicts and the location of the border may be simultaneously determined. Finally, we focus on the subsample of African countries only, who arguably have more "artificial" externally imposed boundaries. Our results remain consistent and robust across these different samples.

We use the Freedom House Political Rights Index as the main measure of institutional quality in this paper. As alternatives, we use the Polity IV index and a binary variable constructed by Acemoglu et al. (2019), and the message of the paper is unchanged.

We provide three sets of further evidence. First, investors must choose whether or not to drill in a given location ("extensive margin") and, given that they drill, how many wells to drill ("intensive margin"). The estimates suggest an increase in the extensive margin of 13%–16% moving from the worse to the better governed side of the border, which translates to a 40%–50% higher likelihood of drilling on the better governed side. The estimated increase in the intensive margin is 33%–54%, although the intensive margin results are somewhat less robust. Second, we examine developing countries and high income countries separately. The pattern of more drilling on the better governed side of the border holds in both samples, with a jump in the number of wells at the border of 156%–195% and 88%–162%, respectively. A larger effect in the developing country sample is consistent with the view that low institutional quality creates headwinds for investments. Third, we break down our results by investor, defined as three different types of companies engaged in the drilling: IOCs (the six supermajors of the oil industry, i.e., Chevron, Shell, BP, ExxonMobil, ConocoPhillips and Total, and their affiliates), NOCs (national oil companies, such as CNPC, PDVSA, Petrobras, or Petronas), and OTHs (the rest of the oil exploration industry, including smaller specialized exploration companies). All company types are found to be sensitive to institutional quality, and we cannot reject that sensitivity to institutional quality is the same across the three company types. However, IOCs are

5. The world's total oil production was 87 million barrels per day in 2013, according to BP Statistical Review of World Energy June 2014. See Cust and Harding (2017) for further details on the back-of-the-envelope calculation.

particularly sensitive to institutional quality in developing countries, whereas OTHs are particularly sensitive to institutional quality in high income countries. NOCs are an intermediate case in both of the two subsamples.

The starting point of this paper is the literature on institutions and economic growth (Hall and Jones 1999; Acemoglu et al. 2001, 2005; Acemoglu and Johnson 2005; Rodrik and Wacziarg 2005; Papaioannou and Siourounis 2008; Dell 2010; Michalopoulos and Papaioannou 2013; Acemoglu et al. 2019). This paper's contribution lies in the identification of investments as a channel through which institutions such as democracy affect growth. We measure investments as the number of exploration wells drilled. Our finding is in agreement with Acemoglu et al. (2019), who find a positive effect of democracy on GDP per capita with investments as a channel. In addition, we present evidence indicating that our findings are not only about foreign direct investments, as both domestic and international companies are responsive to the quality of institutions.

This paper also contributes to the literature on the use of natural resources. Our finding supports work by Bohn and Deacon (2000). Under plausible assumptions for oil, their theory model suggests a positive relationship between better ownership security and investment, and they confirm this empirically in a cross-country analysis. This finding stands in contrast to the earlier conventional view that weak property rights increase current extraction in expectation of higher expropriation risk and hence lower marginal returns in the future (Long 1975). Our paper improves on the empirical analysis of Bohn and Deacon (2000) by using micro data on oil exploration and an identification strategy utilising plausibly exogenous variation in institutional quality.[6]

Our finding means that some types of natural capital are economic outcomes. Like human and physical capital, their accumulation (discovery) depends on institutions. This has immediate consequences for the understanding of the determinants of "Wealth of Nations", as measured by the World Bank (2018). It also has implications for the use of oil variables as explanatory variables in regressions, for example, in the literature on the natural resource curse.[7]

6. The natural resource literature on how resource use varies across levels of development has been concerned with the common pool aspect of natural resources, see, for example, Bohn and Deacon (2000), Jacoby et al. (2002), Long (1975), and Laurent-Lucchetti and Santugini (2012). A related literature has focused on foreign direct investment under the risk of expropriation, see, for example, Thomas and Worrall (1994) and Janeba (2002). The literature on oil exploration more generally has either been theoretical or focusing on mature economies like United States, United Kingdom, Canada, and Norway, and has in both strands been less concerned with the institutional setting. See, for example, Hendricks and Porter (1996), Hurn and Wright (1994), Livernois and Ryan (1989), Mohn and Osmundsen (2008), Pesaran (1990), Quyen (1991), and Venables (2014).

7. For the literature studying the causality running from oil to political (and economic) outcomes, our finding calls for caution. There will be a positive bias in a regression of institutional quality on some oil measure correlated with exploration if the simultaneity is not tackled properly. Cassidy (2016) finds such a bias in his work on the long-run effects of oil wealth on development. See summary by van der Ploeg (2011), and Andersen and Aslaksen (2008), Andersen and Ross (2014), Brunnschweiler and Bulte (2008), Haber and Menaldo (2011), Jensen and Wantchekon (2004), Mehlum et al. (2006), van der Ploeg and Poelhekke (2010), Ross (2001), and Tsui (2011) for papers dealing with the resource curse

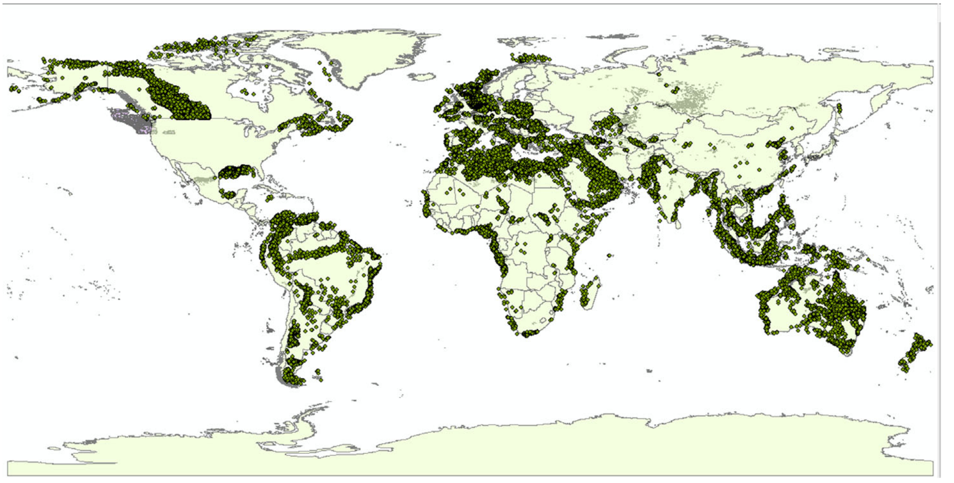

FIGURE 1. National borders and exploration wells.

The paper proceeds as follows. The next section describes the data and outlines the identification strategy. Section 3 presents the baseline results. Section 4 presents estimates for three subsamples focusing on early borders, borders without military disputes and African borders. Section 5 presents estimates for the extensive and intensive margins of drilling, separate estimates for developing countries and high income countries and separate estimates for three different types of investors. Section 6 offers concluding remarks.

2. Empirical Strategy

2.1. Data

Oil exploration data are provided by the PathFinder database owned by Wood Mackenzie (2011), which covers more than 100,000 individual wells in over 120 countries. This proprietary database approaches comprehensive global coverage and is, to our knowledge, the largest collection of the world's exploration wells. It includes a wide range of country and operator reported information assembled historically and updated on a quarterly basis. We utilise information on the exact location of each well and the year when drilling started. Figure 1 shows the global distribution of wells available.

and democracy/institutions. Tsui (2011) and Cotet and Tsui (2013) aim for tackling the endogeneity of oil wealth by using initial resource wealth or discovery rates as instruments and Cassidy (2016) by using information about geological basins.

Data for onshore national borders are from the GADM database of Global Administrative Areas version 2.0 (Hijmans et al. 2010) and for offshore maritime borders the EEZ Maritime Boundaries Geodatabase version 6.1 (Claus et al. 2014). We only include borders that have not changed since 1965, according to the CShapes data set from Weidmann et al. (2010). We define this as either that the home country of the observed well has had stable borders since 1965, or that the nearest neighbour has had stable borders, thus ensuring the border region has remained stable during this period. For sensitivity checks, we further restrict our sample to country pairs where the border has remained unchanged since 1946 or before. For this additional restriction we use the TerrChange database V4.1 (Tir et al. 1998), which has information extending further back in time.

We define our unit of observation as a bin of 1 km width, stacked from a given national border in a given country. We calculate the distance from each well to the closest national border and sum the number of wells drilled in each bin.[8] We create zeros, that is, points without exploration wells, by throwing one million points randomly on the earth.[9]

Our baseline measure of institutional quality, denoted *FH*, is the augmented Freedom House variable from Acemoglu et al. (2008) based on the Freedom House Political Rights Index.[10] As normalised by the authors, the variable is measured on a zero to one scale, with closer to one indicating closer to an ideal set of democratic institutions such as free and fair elections and the presence of electoral competition. As an alternative measure of institutional quality, we consider *Polity*, which is the composite Polity score from the widely used Polity IV database. The measures are defined as $Polity = Democ - Autoc$ and is measured on a -10 to 10 scale.[11] Finally we consider a binary indicator for whether a country has been through a democratic transition, drawn from Acemoglu et al. (2019). This measure codes democracies as 1

8. We calculate straight-line distances from individual exploration wells to nearest borders and nearest neighbours using the "near" point-to-line function of ArcGIS. The distance from the border is measured to the midpoint of the distance-bin. For example, the tenth distance-bin is measured at 9.5 km from the border and will include all wells drilled from 9 to 10 km from the border.

9. This approach gives us coordinates for all the zeros, which allows us to run robustness tests with Conley standard errors to adjust for spatial correlation. We also use these coordinates together with the coordinates from our actual wells to define an alternative sample in which we fill in zeros in all possible distance-bins. A possible distance-bin is then defined as one that falls between a specific border and the maximum distance observed from that border in our combined set of actual wells and random points. The results from this alternative approach yields the same results as our baseline specification (see Table B.2 in Online Appendix B). Note that we include only points that fell within geological basins. Also, we include only points in countries that are not known to have oil production, as we want true zeros rather than missing data. We use the data set of Paasha Mahdavi and Michael Ross to identify if a country has had oil or gas production over the period 1932–2011 and 1955–2011, respectively. This data set can be found here: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/ZTPW0Y.

10. The data can be found at: https://www.aeaweb.org/articles.php?doi=10.1257/aer.98.3.808.

11. The Polity data are from the "Polity IV: Regime Authority Characteristics and Transitions Datasets". They can be downloaded from http://www.systemicpeace.org/polityproject.html. We follow Acemoglu and Johnson (2005) and treat "interregnums" as missing values.

for all years of this regime type, and 0 otherwise. We refer to this measure as *ANRR* and use the values in 1965.[12]

To control for GDP per capita, we use "Output-side real GDP at chained PPPs (in mil. 2011USD)/Population (in millions)" from the Penn World Table 9.0. We use the average of the available values before 1966.[13] Data on country size and landlocked status are from CEPII.[14] See Section 2.2 for how we include the variables in the regressions.

We use all countries available. We exclude all formally "disputed areas" in the data, given the unclear and contested ownership of such areas.[15] We limit the sample to borders stable since at least 1965, as explained previously. We always condition on that we observe our controls, to avoid that estimates change due to sample size differences across alternative specifications.

We do several subsample analyses. In Section 4.1, we first use a cut-off of 1946 for the stable borders instead of 1965, as explained previously. We then exclude borders with observed military disputes, defined by employing the Dyadic MID data set used by Martin et al. (2008). We exclude borders with conflicts of any level that started after 1965.[16] We also consider only countries in the World Bank's Sub-Saharan region plus the North African countries in the World Bank's Middle East and North Africa region.[17] In Section 5.2, we split the sample into developing countries and high income countries, using the World Bank's country classification based on GDP per capita. In Section 5.3, we use information in the PathFinder database Wood Mackenzie (2011) to split the sample into three types of investors: Major International Oil Companies (IOC), National Oil Companies (NOC), and Others (OTH). Table A.1 presents descriptive statistics and Table A.2 presents the list of included host and neighbouring countries.

2.2. Estimation Strategy

Three sources of endogeneity may induce bias when estimating the effect of institutional quality on oil exploration. The first is that the geology (the actual likelihood of discovering oil) is not observable to us. The second is that institutional quality is itself an outcome that can be affected by the investment activities under study. The third is that the territory of countries may be correlated with both geology and institutional

12. The ANRR data can be accessed from Acemoglu's site: https://economics.mit.edu/faculty/acemoglu/data/ddcg.

13. The data was downloaded December 2016 from http://www.rug.nl/ggdc/productivity/pwt/.

14. The data can be found at: http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

15. Disputed areas are limited to offshore regions only, and are defined by the maritime border geodatabase Claus et al. (2014).

16. The data set codes MIDs with a hostility level ranging from 1 to 5, where 1 = No militarized action, 2 = Threat to use force, 3 = Display of force, 4 = Use of force, and 5 = War. The data set (version 2.0) is presented by Zeev Maoz (2005) at: http://cow.dss.ucdavis.edu/data-sets/MIDs.

17. We use World Bank's definition of developing countries and geographical regions, as of July 2012. For more information, see http://datatopics.worldbank.org/world-development-indicators/stories/the-classification-of-countries-by-income.html.

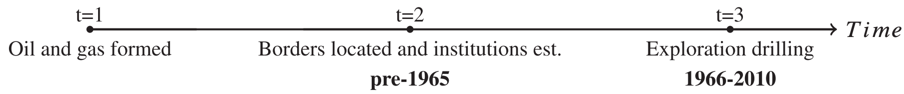

FIGURE 2. Sequence of events in our sample.

quality. We seek to overcome these three identification challenges by taking advantage of the location of oil exploration relative to national borders and by utilising the particular sequencing of events in our setting.

National borders assign institutions to an area. Data on the precise location of oil wells and national borders allow for a regression discontinuity design, as potential geological deposits of oil often stretch across national borders.[18] By studying oil exploration close to borders, we obtain sharp variation in institutions for the same geology. To deal with the potential simultaneity between activities in the oil sector and institutional quality, we use predetermined institutional quality, that is, measured before the drilling took place. Finally, to make sure that the location of the national borders is not affected by the oil exploration we consider, we include only borders that have not changed during our period of oil exploration.

Figure 2 details the sequence of events. The true distribution of oil and gas deposits is determined by prehistoric geological processes, taking place in period 1. In period 2, we posit that national borders were located and institutions were formed. In period 3, exploration drilling for oil takes place. We choose to define period 2 as 1965 and earlier because Weidmann et al. (2010) provide data on countries that have not changed shapes since 1965.[19] We measure institutions as the country-average across 1950–1965 for the Freedom House and Polity measures and use 1965-values for ANRR. Period 3 is defined as 1966–2010 and we include wells drilled in this period only. To deal with path-dependency, we present specifications with the number of wells drilled before 1966 as a control variable.

In a country-pair, we place the country with the better institutional score on the right hand side of the border, following Michalopoulos and Papaioannou (2013). Pooling observations on the left and right hand side, we model the effect of national borders on oil exploration as

$$\ln E(W_{bij}) = \alpha + \tau Dins_{ij} + f_r(X_{bij}) + Dins_{ij} f_r(X_{bij}) + Z'_{ij}\delta_0. \qquad (1)$$

W is the count of exploration wells including zeros and we estimate equation (1) by Poisson regression.[20] The unit of observation is a distance-bin b in country i close to the border with country j. A distance-bin is defined as a 1 km wide strip following

18. See Imbens and Lemieux (2008), Imbens and Wooldridge (2009), and Lee and Lemieux (2010) for thorough explanations and discussions of regression discontinuity (RD) designs.

19. See Section 2.1 for more information on the data from Weidmann et al. (2010). We provide sensitivity checks on the choice of borders in Section 4.1.

20. $E(W)$ is the conditional mean of the number of exploration wells, W. Our explorations showed almost identical results when we used the negative binomial regression model instead of the Poisson model.

along the border. α is a constant and *Dins* is a dummy variable taking the value of one on the side of the border with the better institutional quality, and zero on the other side. The assignment variable, X, is the distance to the border. The polynomial f controls for unobservable determinants of drilling with respect to the distance to the border and we allow it to differ by interacting with the border dummy *Dins*. Z is a vector of dummies explained in what follows. τ picks up a jump in the mean at the discontinuity, that is, the effect of crossing the national border on exploration drilling. Note that institutional quality enters equation (1) only in an ordinal sense, that is, by determining the ranking of the two countries. Simultaneity between drilling and the quality of institutions would therefore only be an issue if the ranking between the two countries were affected.

We also run OLS models for one of the three following dependent variables:[21] $\ln(W+1)$, $D=1$ and $\ln W$, where $D=1$ is a dummy variable taking one if a distance-bin b in country i close to the border with country j has at least one well drilled and zero otherwise. We call $D=1$ the extensive margin and $\ln W$ the intensive margin.[22]

To estimate how responsive oil exploration is to a given change in institutional quality, we scale the jump at the border with the difference in institutional quality between the bordering countries. We do this by using the border dummy as an instrument for the difference in institutional quality, with either IV Poisson GMM or 2SLS estimation.[23]

Control variables may increase efficiency in an RD-design (Imbens and Lemieux 2008; Lee and Lemieux 2010). Partly for this reason and partly to ensure that the results are not driven by omitted characteristics, we use four different set of controls. The first is no controls, the second adds a bilateral dummy for initial GDP per capita, the third adds a bilateral dummy for initial drilling and the fourth adds a bilateral dummy for area size as well as a unilateral dummy for landlocked status. Analogous to the border dummy for institutional quality, all the dummies take one for the country in the border-pair with the higher value on the characteristic in question.

Controlling for the bilateral ranking in initial GDP per capita allows us to estimate the effect of institutions for a given ranking of initial economic development. This is intended to capture any variation across borders that is better explained by differences in income rather than institutional quality, for example, human capital, physical capital, or the availability of financial capital. The bilateral dummy for initial drilling accounts for potential path dependency, that is, previous investments in the sector may affect the profitability of drilling. The geographic controls, area size and landlocked status, are found to have effects in the international trade and investment literature. In our setting, the size of the country affects the area available for exploration and hence potentially the

21. The OLS models can be expressed as $Y_{bij} = \alpha + \tau Dins_{ij} + f_r(X_{bij}) + Dins_{ij} f_r(X_{bij}) + Z'_{ij}\delta_0 + u_{bij}$, where Y is a placeholder for one of the three dependent variables and u is the error term.

22. As discussed in the trade literature, the extensive margin can be defined at many levels of aggregation. We regard the *bij*-level as the most natural definition given the variation in our data.

23. We obtain Poisson estimates by the poisson and ivpoisson gmm routines in Stata, and OLS and two-stage least squares estimates by the ivreg2 module Baum et al. (2002) in Stata.

number of wells drilled. Landlocked status may affect transport costs asymmetrically across the borders and thereby affect the profitability of drilling asymmetrically, for example, crossing the border for transport may be costly.

The choice of bandwidth in a RD-design is a trade-off between bias and efficiency (Lee and Lemieux 2010). The RD-assumption of comparable areas on both sides of the border is most likely to be valid for small bandwidths (bandwidth = distance to the border). Inclusion of observations further away from the border improves the efficiency of the estimators, however. In our setting, optimal bandwidth selection based on local linear polynomials suggests bandwidths around 75 km. Thus, we focus on observations within 75 km and linear polynomials. For transparency, we expand all tables in the paper (Tables 2–9) to include 10, 75, and 150 km bandwidths and no polynomials, linear polynomials and quadratic polynomials in Tables B.2– B.9 of Online Appendix B.[24]

We use two-way clustered standard errors. We cluster on country (indicated *iso*) to take into account that home countries have several borders included and on border-region (indicated *border*2*way*) to take into account potential spatial correlation. The latter means that observations in Uganda and observations in DR Congo located along the border between the two countries will belong to the same cluster. For the Poisson estimates, we implement the two-way clustering by the vce2way module Yoo (2017) and for the three other models with the ivreg2 module Baum et al. (2002), both in Stata.[25]

3. Baseline Results

3.1. Graphical Presentation and Descriptive Statistics

Table 1 provides descriptive statistics for the number of exploration wells within 75 km of national borders. Out of a total of 22,977 wells in this sample, 7,562 are drilled on

24. Of the 110,000 wells in the full data set of exploration wells, 49.5%, 72.7%, and 83.4% are within 75, 150, and 250 km from the borders, respectively. We used the rdrobust package in Stata (Calonico et al. 2014; Calonico 2017) for bandwidth selection. Table B.11 in Online Appendix B presents our baseline estimates together with estimates from rdrboust, with optimal bandwidth selection and local linear polynomials based on both triangular and uniform kernels. The uniform kernel is weighting all observations equally, as does our baseline approach. When we allow for automatic bandwidth selection, we start out from a sample of wells located within 250 km of the borders. We use the default settings of "mserd", which specifies one common mean squared error (MSE)-optimal bandwidth selector for the RD treatment-effect estimator. The bandwidths are the same on each side of the border. For the standard errors, we use the cluster option, but are only able to cluster one way, which we set to the country-level. We present results for the dependent variable $\ln(W + 1)$, as we have not found a way to combine Poisson with local linear estimation. We include estimates for *FH*, *Polity*, and *ANRR*. The optimal bandwidths vary between 53 and 89 km. Our judgement of the results in Table B.11 in Online Appendix B is that a bandwidth of 75 km and a linear polynomial is a reasonable choice in our setting.

25. As a robustness check regarding potential spatial correlation, we present in Table B.13 in Online Appendix B estimates with standard errors estimated with the GMM-method of Conley (1999), as implemented by the program of Hsiang (2010). We corrected the small mistake in Hisang's code, following Darin Christensen and Thiemo Fetzer (https://darinchristensen.com/post/2017-08-21-correction/). Conley-standard errors produce much smaller p-values in our setting.

TABLE 1. Descriptive statistics on the total drilling.

		75 km				
		Total	LHS	RHS	Difference	p-value
Total	No. obs.	9516	4627	4889		
	ln(W+1)	0.56	0.47	0.64	0.17	0.00
	W	2.41	1.63	3.15	1.52	0.00
	W total	22977	7562	15415		

Notes: Table shows baseline sample means for the number of wells and its log-transformation, alongside with the number of observations and the total number of wells. The numbers are for the full sample as well as for the left hand side (LHS) and the right hand side (RHS) of the border separately. Table B.1 in Online Appendix B shows this table also for 10 and 150 km bandwidths. The p-values are from a t-test of the difference in means between LHS and RHS.

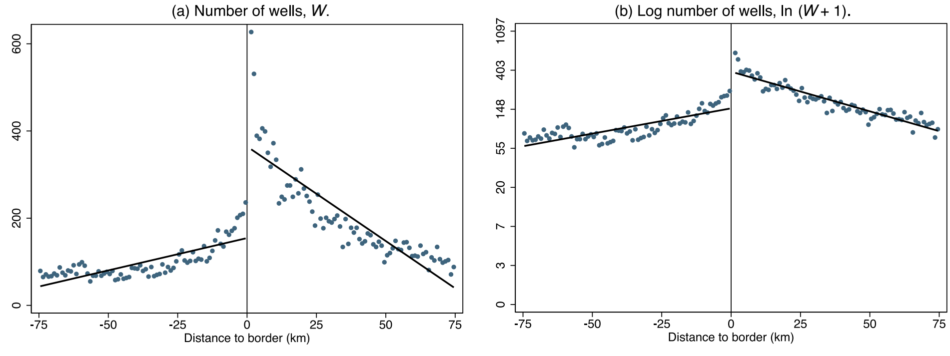

FIGURE 3. RD-plots: Drilling around national borders. Notes: Based on full sample (defined in Section 2.1). Distance to border in km on the x-axis. Countries at a given border placed left or right of zero depending on their bilateral ranking in terms of the Freedom House Political Rights Index, with the higher ranked country to the right. The y-axes show the number of wells per distance-bin across countries: Panel (a) shows the level and panel (b) shows the log of the number of wells+1. The width of a distance-bin is 1 km. Lines show first order polynomial in distance to the border. Figure B.2 in Online Appendix B shows this graphs also for 10 and 150 km bandwidths.

the side of the borders with weaker institutional quality (LHS) and 15,415 are drilled on the side with the better institutional quality (RHS).

The left panel of Figure 3 shows the total number of wells for each 1 km bin up to 75 km from national borders. On both sides, the number of wells fall as we move away from the borders. This pattern is partly an artefact of the bins covering less additional land area as we move towards the inside of the countries and that not all countries are large enough to be included for large distances.[26] Comparison with the linear trend-lines shows that the number of wells decreases nonlinearly. The right hand side

26. From the max sample of 88 countries at the border in our 150 km baseline sample, 86 countries are represented at distances above 25 km, 78 at distances larger than 75 km, and 68 at distances larger than 125 km. Out of the total of 22,977 wells in our 75 km FH-sample, 2,926 (12.7%) are within 3 km from the border in 83 different countries.

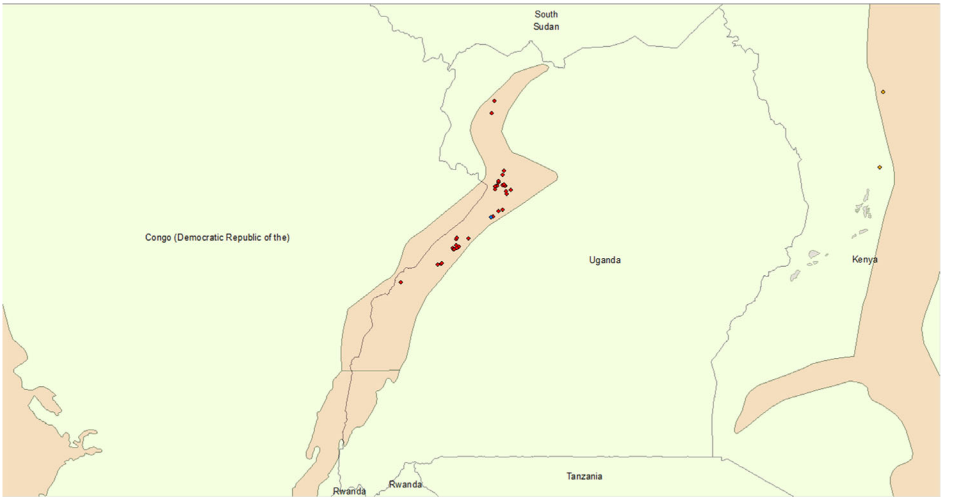

FIGURE 4. Map of Albert Rift region along Uganda-DRC border. Albert Rift basin indicated, along with exploration wells, notably concentrated on the Ugandan side of the border with DRC.

panel of Figure 3 shows instead a log-linear transformation of the number of wells, making the relationship closer to linear. In both plots, there is a striking discontinuity in drilling at the border, with much more drilling on the better governed side of the border. In what follows we formally estimate the jump at the border, and the two plots correspond to our baseline estimates.

Figure 4 illustrates the data along a single border. Here we observe drilling on the Ugandan side of the Albert Rift geological basin, but no exploration on the Democratic Republic of the Congo (DRC) side. Given that the oil basin spans both sides of the border, we would not expect, ex ante, for drilling to be more promising on one side of the border than the other for purely geological reasons. Our hypothesis is that institutions influence the drilling decision, and thus the observed distribution of wells would be positively correlated with the relative quality of institutions locally.

In 2013, Uganda's Freedom House Political Rights Index score was 4.5 (*Partly free*), whereas the score for the DRC was 6 (*not free*).[27] The first well was drilled in pre-independence Uganda in 1938 but was unsuccessful. It was not until the early 2000s that exploration drilling restarted. Since 2002 several dozen exploration wells have been drilled. SacOil and Total reported in 2016 on seismic testing on the DRC side of the border, and the former stipulated first exploration well to be drilled in

27. Note that we use as our baseline measure of institutional quality an augmented version of the Freedom House Political Rights Index measure provided by Acemoglu et al. (2008). This is normalised to a zero to one scale, where one means a country comes closest to the political rights ideals suggested by a checklist of questions.

2018, 16 years after Uganda.[28] This delay (at best) of exploration drilling on the DRC side of the border, is consistent with a positive effect of institutional quality on oil exploration.

Several countries have seen evolution in their democratic institutions during our sample period and have recorded associated changes in drilling activity. Ghana, for example, saw strong improvements in their democratic governance scores from 1990s onwards and have seen increased and high sustained drilling activity since the late 1990s, leading to major oil discoveries in 2007 onwards and now a nascent oil sector. Thailand similarly saw progress on democratic institutions in the 1990s and associated increases in drilling activity. Venezuela's shift away from democracy since the 1990s has been accompanied by a decline in exploration drilling.[29]

3.2. Baseline Estimates

Table 2 presents RD-estimates of the jump at the border. Columns (1)–(4) show Poisson estimates with the simple count of wells (W) as the dependent variable and successively more controls added as we move from columns (1)–(4). In the same fashion, columns (5)–(8) provide OLS-estimates with the dependent variable defined as $\ln(W + 1)$. We include linear polynomials separately on each side of the border in all columns. Consistent with optimal bandwidth selection, we include wells located up to 75 km from the borders. See Section 2.2 for discussions on these estimation choices.

All the estimated coefficients on the institution dummy are positive and significant, and they are stable across the different sets of controls. In the W-models, the estimated coefficients are between 0.816 and 1.016. They translate to incidence ratios between 2.26 and 2.76, equivalent to 126%–176% more wells on the better governed side of the border. Exploration companies invest on the side of the border with better institutional quality in more than 2 out of 3 times.

The $\ln(W + 1)$ models give qualitatively the same conclusion, although the magnitudes are smaller, with 36%–46% more wells on the better governed side of the border. However, Poisson is the preferred regression model for a count variable containing many zeros, such as our number of exploration wells W. With the exception

28. According to https://www.engineeringnews.co.za/article/sacoil-says-drc-drilling-may-start-in-2017-after-positive-exploration-results-2016-07-29/rep_id:4136 Engineering News, July 29, 2016, on SacOil and https://uk.reuters.com/article/uk-total-congodemocratic/total-conducting-seismic-testing-on-congo-oil-block-idUKKCN0VD2KP Reuters, February 4, 2016, on Total.

29. We do not separate between demand and supply effects in this paper. Disinvestments from Iran by international investors during the 1990s and early 2000s, due to operating terms and escalating political tension, illustrates the demand side. Mexico banned oil drilling by foreign companies between 1938 and 2013 and serves as an illustration of restricted supply. This may have contributed to the sharp asymmetry in drilling across the US–Mexico border in the Gulf of Mexico. The Iran example is from the Financial Times 2 November 2016: https://www.ft.com/content/06acb822-95fe-11e6-a80e-bcd69f323a8b. For news coverage of the investment law in Mexico, see the article from BBC December 21, 2013: http://www.bbc.com/news/world-latin-america-25471212.

TABLE 2. Baseline estimates.

	W (1)	W (2)	W (3)	W (4)	ln (W+1) (5)	ln (W+1) (6)	ln (W+1) (7)	ln (W+1) (8)
$D = 1$ rhs FH	0.884	0.816	1.016	0.999	0.327	0.306	0.380	0.360
	(0.015)	(0.013)	(0.000)	(0.001)	(0.010)	(0.009)	(0.000)	(0.000)
$D = 1$ rhs GDPCAP		0.685	0.319	0.297		0.198	0.079	0.057
		(0.081)	(0.365)	(0.395)		(0.103)	(0.457)	(0.600)
$D = 1$ rhs Wpre66			1.639	1.293			0.546	0.441
			(0.000)	(0.000)			(0.000)	(0.000)
$D = 1$ rhs Area				0.402				0.104
				(0.104)				(0.213)
Landlocked				−1.909				−0.311
				(0.000)				(0.000)
Mean L	1.63	1.63	1.63	1.63	0.47	0.47	0.47	0.47
Observations	9516	9516	9516	9516	9516	9516	9516	9516
Countries	88	88	88	88	88	88	88	88
Neighbours	88	88	88	88	88	88	88	88
R-sq.					0.020	0.031	0.114	0.128
Clusters (iso)	88	88	88	88	88	88	88	88
Clusters (border2way)	130	130	130	130	130	130	130	130

Notes: Dependent variable indicated in column headings, where W is the number of wells including zeros. Based on full sample (defined in Section 2.1). An observation is a 1 km distance-bin in home country i, close to the border of neighbouring country j. *D = 1 rhs FH* takes one if country i has higher score on the augmented Freedom House political rights index than country j, and zero otherwise. Analogously, controls are dummies taking one if country i has the highest value on initial GDP per capita, previous drilling and country area size. Landlocked is a dummy taking one if country i is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. Columns (1)–(4) estimated with Poisson maximum-likelihood, columns (5)–(8) estimated with OLS. p-values in parentheses based on two-way clustering on country and border-region. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Table B.2 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials. Figure B.2 in Online Appendix B presents the associated RD-graphs.

of next section, where we present scaling also with 2SLS for $\ln(W+1)$ models, we focus on Poisson estimates for the total number of wells hereafter.[30]

Our estimates are based on a cross section of wells drilled from 1966 to 2010, that is, the accumulated exploration drilling over 45 years, and we interpret them as being close to long-run estimates. Our results are in line with Acemoglu et al. (2019), Papaioannou and Siourounis (2008), and Rodrik and Wacziarg (2005), who have found a positive effect of democracy on economic growth.

3.3. IV: Scaling with Jump in Institutional Quality

To obtain an estimate of the responsiveness of exploration drilling to a given change in institutional quality, we use in this section the border-dummy for institutional quality as an instrument for the jump in the institutional score at the border. Thus we bring in a cardinal interpretation of institutional quality, in contrast to the purely

30. The effect in the Poisson model is given by $e^{0.816} - 1 = 1.26$ and in the log-linear model by $e^{0.306} - 1 = 0.36$.

ordinal dummy, which is based only on the rank of the two neighbours. Although transforming something as complex as institutional quality into a cardinal score may be a challenging task, a cardinal interpretation is not uncommon in the literature (e.g., Acemoglu and Johnson 2005).

The estimates are presented in Table 3. The format is the same as previously, with IV Poisson-estimates to the left and log-linear 2SLS-estimates to the right. First stage estimates are not available for the IV Poisson estimation, but for 2SLS we report them in the lower panel. Columns differ by the set of controls, as before, but now we use the level difference between the two neighbours, analogous to the use of a cardinal institutions measure.

The first stage estimates (bottom panel of Table 3) show that crossing the borders in our sample gives on average a jump in the Freedom House score of around 0.4 (the positive coefficient is by construction). This demonstrates considerable variation in institutional quality at the borders in our sample. For comparison, the jumps at the borders have a standard deviation of 0.291 (see Table A.1). All the first stage estimates are statistically significant and the F-statistics are strong (around 95), which is not surprising given that the border dummy is constructed based on the ranking in terms of the Freedom House scores.

The second stage coefficient in the Poisson regression of 2.108 implies that a jump at the border equal to one standard deviation (0.291), increases the drilling by 85%. For comparison, the difference in FH between DRC and Uganda is exactly 0.29. Across the different specifications, the Poisson estimates suggest an increase of 77%–94%. The log-linear specifications suggest 25%–29% more wells drilled as the institutional quality jumps by one standard deviation.[31] As before, the Poisson models of Columns (1)–(4) are our preferred models, but we show the 2SLS estimates for $\ln(W + 1)$ for transparency and because it allows us to present a first stage.

4. Sensitivity

4.1. Subsets of Borders

Our identification strategy rests on the assumption that borders were drawn independently of oil deposits. Our baseline sample contains only stable and well-defined borders. However, in Table 4 we stress-test the central assumption of independent borders further by focusing on three stricter subsamples of borders. See Section 2.1 for details on the data.

31. As an example, the effect in the Poisson model is given by $e^{2.108*0.291} - 1 = 0.85$ and in the log-linear model by $e^{0.805 \times 0.291} - 1 = 0.26$. Note that the "reduced form" estimate of 0.327 in column (5) in Table 2 divided on the first stage coefficient of 0.406 in column (5) in Table 3, yields the second stage coefficient of 0.805.

TABLE 3. IV estimates.

	Second stage							
	W (1)	*W* (2)	*W* (3)	*W* (4)	ln (*W*+1) (5)	ln (*W*+1) (6)	ln (*W*+1) (7)	ln (*W*+1) (8)
Δ FH	2.108	1.969	2.241	2.269	0.805	0.775	0.867	0.834
	(0.010)	(0.013)	(0.001)	(0.002)	(0.012)	(0.014)	(0.001)	(0.002)
−/+ln abs(Δ GDPCAP)		0.029	0.000	−0.004		0.006	−0.002	−0.004
		(0.317)	(0.993)	(0.881)		(0.471)	(0.792)	(0.613)
−/+ln abs(Δ Wpre66+1)			0.179	0.146			0.048	0.036
			(0.000)	(0.000)			(0.000)	(0.000)
−/+ln abs(Δ Area)				0.017				0.006
				(0.177)				(0.165)
Landlocked				−1.875				−0.382
				(0.000)				(0.000)
Mean *L*	1.63	1.63	1.63	1.63	0.47	0.47	0.47	0.47
Observations	9516	9516	9516	9516	9516	9516	9516	9516
Countries	88	88	88	88	88	88	88	88
Neighbours	88	88	88	88	88	88	88	88
R-sq.					0.011	0.015	0.082	0.108
Clusters (iso)	88	88	88	88	88	88	88	88
Clusters (border2way)	130	130	130	130	130	130	130	130
F instr.					93.74	97.85	97.57	93.88
R-sq. 1st shea					0.206	0.210	0.209	0.208
					First stage			
					Δ FH (1)	Δ FH (2)	Δ FH (3)	Δ FH (4)
$D = 1$ rhs FH					0.406	0.386	0.383	0.382
					(0.000)	(0.000)	(0.000)	(0.000)
−/+ln abs(Δ GDPCAP)						0.010	0.011	0.011
						(0.000)	(0.000)	(0.000)
−/+ln abs(Δ Wpre66+1)							−0.004	−0.004
							(0.249)	(0.388)
−/+ln abs(Δ Area)								−0.000
								(0.837)
Landlocked								−0.014
								(0.661)

Notes: Dependent variable indicated in column headings, where *W* is the number of wells including zeros. Based on full sample. An observation is a 1 km distance-bin in home country *i*, close to the border of neighbouring country *j*. $D = 1$ *rhs FH* takes one if country *i* has higher score on the augmented Freedom House political rights index than country *j*, and zero otherwise. Analogously, controls are dummies taking one if country *i* has the highest value on initial GDP per capita, previous drilling, and country area size. Landlocked is a dummy taking one if country *i* is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. Columns (1)–(4) estimated with Stata's Poisson maximum-likelihood estimator (ivpoisson gmm), columns (5)–(8) estimated with 2SLS. *p*-values in parentheses based on two-way clustering on country and border-region. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Table B.3 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials.

Borders Stable Since 1946. Instead of 1965 as in the baseline sample, we now use 1946, just after the second world war ended, as an earlier stable border cu*t*-off date. The estimates, shown in columns (1)–(4) in Table 4, reveal that our results are robust to limiting the sample to these more established borders. The magnitudes suggest a

TABLE 4. Stable borders.

	1946 borders				No military disputes borders				African borders			
	W (1)	*W* (2)	*W* (3)	*W* (4)	*W* (5)	*W* (6)	*W* (7)	*W* (8)	*W* (9)	*W* (10)	*W* (11)	*W* (12)
$D = 1$ rhs FH	0.653	0.569	0.765	0.752	1.070	0.989	1.193	1.227	1.667	1.825	2.113	2.196
	(0.053)	(0.054)	(0.001)	(0.003)	(0.032)	(0.033)	(0.003)	(0.003)	(0.058)	(0.015)	(0.001)	(0.006)
$D = 1$ rhs GDPCAP		0.558	0.277	0.256		0.909	0.410	0.345		1.781	0.886	0.745
		(0.223)	(0.509)	(0.536)		(0.057)	(0.381)	(0.455)		(0.000)	(0.059)	(0.133)
$D = 1$ rhs Wpre66			1.538	1.336			1.666	1.291			2.351	1.291
			(0.000)	(0.000)			(0.000)	(0.000)			(0.000)	(0.043)
$D = 1$ rhs Area				0.372				0.595				0.997
				(0.065)				(0.089)				(0.280)
Landlocked				−1.591				−1.432				−2.472
				(0.000)				(0.000)				(0.004)
Mean *L*	1.98	1.98	1.98	1.98	1.46	1.46	1.46	1.46	0.90	0.90	0.90	0.90
Observations	6721	6721	6721	6721	6978	6978	6978	6978	2132	2132	2132	2132
Countries	60	60	60	60	80	80	80	80	28	28	28	28
Neighbours	64	64	64	64	81	81	81	81	28	28	28	28
Clusters (iso)	60	60	60	60	80	80	80	80	28	28	28	28
Clusters (border2way)	86	86	86	86	99	99	99	99	37	37	37	37

Notes: Dependent variable is *W*, the number of wells including zeros. Columns (1)–(4) based on borders stable since 1946, columns (5)–(8) based on borders without military disputes after 1965, and columns (9)–(12) based on African borders only. An observation is a 1 km distance-bin in home country *i*, close to the border of neighbouring country *j*. $D = 1$ *rhs FH* takes one if country *i* has higher score on the augmented Freedom House political rights index than country *j*, and zero otherwise. Analogously, controls are dummies taking one if country *i* has the highest value on initial GDP per capita, previous drilling, and country area size. Landlocked is a dummy taking one if country *i* is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. All columns estimated with Poisson maximum-likelihood. *p*-values in parenthesis based on two-way clustering on country and border-region. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Table B.4 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials. Figure B.4 in Online Appendix B presents the associated RD-graphs.

jump at the border of 77%–115% in the number of wells, which is somewhat smaller than the 126%–176% jump in the baseline sample.

Borders without Military Disputes. In columns (5)–(8) in Table 4, we exclude from the sample borders with any instances of known interstate conflicts starting after 1965. Caselli et al. (2015) argue that the distance from the border to an oil field is a predictor of bilateral wars. However, they do not identify many incidents of borders actually moving, nor that any such effect should systematically work in favour of neighbours with more democratic institutions. Nevertheless, even if the border remains stable, inter-state conflict could interfere with oil exploration, for example, by preventing companies entering the conflict zone. The results show that the estimates in the restricted sample are somewhat larger than the baseline estimates, with a jump in the number of wells of 169%–241%.[32]

32. Note that the threat alone of moving a border via conflict or threat of conflict, or the temporary occupation should not harm our identification directly. See Caselli et al. (2015) and Acemoglu et al. (2012) for more on resource wars.

Africa Only. In an attempt to restrict our sample to countries with more artificial borders, we examine African countries only in columns (9)–(12) in Table 4. The arbitrary nature of some of the African borders is illustrated by very straight borders. These are therefore considered to have been drawn with little regard for local human or natural conditions, such as ethnic groups, geography or indeed geology.

The results show again positive and statistically significant coefficients on the institutions border dummy. The magnitude in the Poisson regressions are now larger, implying a jump in the number of wells of 430%–799%. Is this due to a higher jump in the institutional quality or higher sensitivity to a given jump in the institutional quality in Africa than elsewhere? Results not shown to save space show that the jump in FH at the borders in the Africa-sample is around 0.36, somewhat smaller than in the full sample. The larger effect in Africa therefore seems to be about higher sensitivity to a given jump in institutional quality.

Could it be that colonial powers were attracted to a given territory because of oil, creating a correlation between institutional quality and oil drilling? We consider this unlikely, as almost all colonization took place long before the location of oil was plausibly known. Furthermore, the colonial powers would need to know very precisely where the oil was located, and draw the border accordingly, since our results are robust to comparison of areas very close to national borders. In contrast to the idea that colonial powers carefully assigned borders according to the presence of natural resources, Alesina et al. (2011) and Michalopoulos and Papaioannou (2016) instead argue that some colonial states received "artificial borders", most notably in Africa.

4.2. Alternative Measures of Institutions

We focus in our baseline estimates on the institution scores drawn from the Freedom House Political Rights Index. As alternative measures, we now turn to the widely used Polity IV measure and a binary measure for democracy from Acemoglu et al. (2019). We refer to the latter as ANRR, and we only include borders for which there is a difference in the democracy status across the border in 1965. Section 2.1 provides more information about Polity and ANRR.

The upper panel of Table 5 presents Poisson estimates using the Polity IV scores in columns (1)–(4) and the ANRR measure in columns (5)–(8). Both measures produce positive and significant coefficients on the institutions border dummy, suggesting an increase in the number of wells moving from the left to the right hand side of the border of between 18% and 22% for Polity and 14%–31% for ANRR. The lower part of Table 5 presents second stage estimates for the Polity measure (this is not available for the ANRR-measure, as it is a dummy that is collinear with the border dummy). A jump in Polity of one standard deviation (7.782), increases the number of wells by 113%–139%. This is somewhat higher than the 77%–94% for an analogous one standard deviation increase in the Freedom House measure. We conclude that the result that exploration drilling responds to institutional quality holds up also for

TABLE 5. Alternative institutional measures.

	Polity				ANRR			
	W (1)	*W* (2)	*W* (3)	*W* (4)	*W* (5)	*W* (6)	*W* (7)	*W* (8)
$D = 1$ rhs INS	0.200	0.191	0.180	0.169	0.272	0.186	0.185	0.132
	(0.008)	(0.013)	(0.018)	(0.025)	(0.001)	(0.000)	(0.001)	(0.077)
$D = 1$ rhs GDPCAP		0.044	0.015	−0.001		0.123	0.024	0.037
		(0.438)	(0.789)	(0.980)		(0.092)	(0.793)	(0.715)
$D = 1$ rhs Wpre66			0.115	0.036			0.155	0.114
			(0.005)	(0.347)			(0.207)	(0.395)
$D = 1$ rhs Area				0.087				0.056
				(0.039)				(0.644)
Landlocked				−0.311				−0.369
				(0.000)				(0.002)
Mean *L*	0.33	0.33	0.33	0.33	0.41	0.41	0.41	0.41
Observations	7773	7773	7773	7773	2559	2559	2559	2559
Countries	63	63	63	63	34	34	34	34
Neighbours	75	75	75	75	39	39	39	39
R-sq.	0.032	0.034	0.047	0.085	0.048	0.055	0.070	0.095
Clusters (iso)	63	63	63	63	34	34	34	34
Clusters (border2way)	103	103	103	103	33	33	33	33
	Second stage							
	W	*W*	*W*	*W*				
Δ Polity	0.112	0.112	0.100	0.097				
	(0.003)	(0.006)	(0.004)	(0.012)				

Notes: Dependent variable is *W*, the number of wells including zeros. Upper panel as Table 2, but with alternative measures of institutions: Polity (columns (1)–(4)) and ANRR (columns (5)–(8)). An observation is a 1 km distance-bin in home country *i*, close to the border of neighbouring country *j*. *D = 1 rhs FH* takes one if country *i* has higher score on the augmented Freedom House political rights index than country *j*, and zero otherwise. Analogously, controls are dummies taking one if country *i* has the highest value on initial GDP per capita, previous drilling and country area size. Landlocked is a dummy taking one if country *i* is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. All columns estimated with Poisson maximum-likelihood. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Lower panel presents second stage estimates for Polity, estimated with ivpoisson gmm, as in Table 3. Scaled estimates not available for ANRR, as ANRR is a dummy variable. *p*-values in parentheses are based on two-way clustering on country and border-region. Table B.5 in Online Appendix B shows the upper part of this table also for 10 and 150 km bandwidths and zero and second order polynomials. It also includes estimates for the Polity subindices for democracy, autocracy, and constraints on the executive branch of government. Figure B.5 in Online Appendix B presents RD-graphs for Polity and ANRR.

these alternative measures of democracy.[33] In the Online Appendix, we also present estimates for the Polity subindices for Democracy, Autocracy and Constraints on the

33. The Polity effect of 113% is calculated as $e^{0.097 \times 7.782} - 1 = 1.13$. In results not shown to save space, a one standard deviation increase in the Polity score is found to increase the number of wells by 43%–48% in log-linear 2SLS models (like column (5)–8 in Table 3, but for Polity). Again suggesting a higher effect for a standard deviation increase in the Polity score than for a standard deviation increase in the FH-score (25%–29%, Table 3). First stage estimates for Polity suggest an average jump when crossing the borders of 10.5–11.7, or 1.35–1.50 standard deviations. The corresponding jumps for FH presented in Table 3 are 0.382–0.406, or 1.31–1.40 standard deviations. The jumps at the borders measured in standard deviations

TABLE 6. Descriptive statistics on the extensive and intensive margins.

		75 km				
		Total	LHS	RHS	Difference	p-value
Extensive	No. obs.	9516	4627	4889		
	$D = 1$	0.36	0.33	0.39	0.06	0.00
Intensive	No. obs.	3472	1550	1922		
	ln W	1.15	1.00	1.28	0.29	0.00
	W	2.41	1.63	3.15	1.52	0.00
	W total	22977	7562	15415		

Notes: Table shows baseline sample means for the extensive ($D = 1$) and intensive margins (ln W). The numbers are for the full samples as well as for the left hand side (LHS) and the right hand side (RHS) of the border separately. Table B.6 in Online Appendix B shows this table also for 10 and 150 km bandwidths. The p-values are from a t-test of the difference in means between LHS and RHS.

executive branch of government. Again the results consistently show that the side of the border with better institutional quality receives more exploration drilling, and that investors prefer to drill in the more democratic, and less autocratic, neighbour.

5. Further Evidence

5.1. Extensive versus Intensive Margin

Previously we have focused on estimates based on total well counts, including zeros. We now break down total drilling into two margins of activity. The extensive margin captures whether a given area is explored or not, whereas the intensive margin captures the extent of exploration given that the area receives exploration. Investors might expand exploration activity along either margin in their search for commercial oil and gas.

Table 6 presents descriptive statistics for the two margins. The extensive margin shows that 33% of the distance-bins on the left hand side have at least one well within 75 km from the border. The corresponding figure for the right hand side is 39%, a statistically significant difference of 6 percentage points. Also for the intensive margin there is a statistically significant difference, with on average 1.63 wells per distance-bin on the left hand side and 3.15 on the right hand side. We use the log of the number of exploration wells as the intensive margin. Figure 5 reveals clear jumps in the extensive margin (left panel) and the intensive margin (right panel) at the borders, with more drilling on the side of the border with relatively better institutions.

Table 7 presents OLS estimates of extensive margin (columns (1)–(4)) and intensive margin (columns (5)–(8)), following the standard format with controls added

are in other words quite similar for Polity and FH. The F-statistics for the first stage of the Polity-models are between 77 and 98.

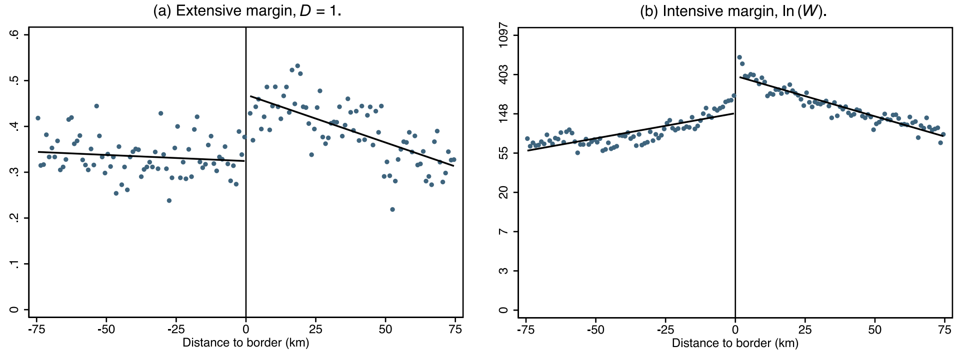

FIGURE 5. RD-plots two margins. Panel (a): The extensive margin shown on the y-axis is defined as the mean of the variable $D = 1$ per bin across countries (the likelihood of observing at least one well in a given distance-bin). Panel (b): The intensive margin shown on the y-axis is the log of total number of wells drilled in the distance-bin across all countries in the sample (number of wells indicated). Based on full sample (defined in Section 2.1). Distance to border in km on the x-axis. Countries at a given border placed left or right of zero depending on their bilateral ranking in terms of the Freedom House Political Rights Index, with the higher ranked country to the right. The width of a distance-bin is 1 km. Lines show first order polynomial in distance to the border. Figure B.7 in Online Appendix B shows this figure also for 10 and 150 km bandwidths.

successively. The extensive margin results show statistically significant jumps at the border, with a 13–16 percentage points higher likelihood of drilling in a given distance-bin on the better side of the border. This corresponds to up to half of the LHS-average of 0.33 for $D = 1$ in our sample.[34] Along the intensive margin, the estimates suggest an increase in drilling of 33%–54%. These intensive margin estimates are statistically significant at conventional levels only when we control for previous drilling. However, expanding Table 7, we estimate a statistically significant jump for the intensive margin in all four models for both the 10 and the 150 km sample (see Table B.7 in Online Appendix B). Furthermore, in results not shown to save space, we find statistically significant jumps in both the extensive and the intensive margin when we use the Polity measure for 75 km bandwidths. For ANRR, the extensive margin jump is statistically significant in all four models, whereas the intensive margin jump is statistically significant at least at the 11% level in three out of four cases. Thus, we conclude that investors respond to institutional quality at both margins.

5.2. Heterogeneity across Countries

Many of the investments in the oil sector may historically have originated in high income countries. Thus, information asymmetry between source and host countries

34. The level of the extensive margin depends on the number of random zeros included in the sample. Our extensive margin is defined with an arbitrary number of zeros, but Table B.12 in Online Appendix B, which is based on zeros in all possible distance-bins within our sample of borders, shows that the number of zeros does not have any large influence on the relative estimates. Both the average and the jump at the border are affected with about the same magnitudes.

TABLE 7. Two margins.

	Extensive margin				Intensive margin			
	$D = 1$ (1)	$D = 1$ (2)	$D = 1$ (3)	$D = 1$ (4)	ln W (5)	ln W (6)	ln W (7)	ln W (8)
$D = 1$ rhs FH	0.141	0.133	0.164	0.150	0.294	0.287	0.413	0.432
	(0.005)	(0.005)	(0.000)	(0.000)	(0.215)	(0.207)	(0.037)	(0.037)
$D = 1$ rhs GDPCAP		0.078	0.028	0.013		0.294	0.069	0.059
		(0.077)	(0.489)	(0.745)		(0.188)	(0.736)	(0.766)
$D = 1$ rhs Wpre66			0.228	0.170			0.668	0.582
			(0.000)	(0.000)			(0.000)	(0.000)
$D = 1$ rhs Area				0.040				0.125
				(0.375)				(0.325)
Landlocked				−0.213				−0.639
				(0.000)				(0.000)
Mean L	0.33	0.33	0.33	0.33	1.00	1.00	1.00	1.00
Scaled L	0.42	0.40	0.49	0.45				
Mean Y	0.36	0.36	0.36	0.36	1.15	1.15	1.15	1.15
Observations	9516	9516	9516	9516	3472	3472	3472	3472
Countries	88	88	88	88	88	88	88	88
Neighbours	88	88	88	88	88	88	88	88
R-sq.	0.008	0.015	0.066	0.088	0.035	0.052	0.127	0.142
Clusters (iso)	88	88	88	88	59	59	59	59
Clusters (border2way)	130	130	130	130	82	82	82	82

Notes: Table shows baseline sample estimates for the extensive ($D = 1$; columns (1)–(4)) and intensive margins (ln W; columns (5)–(8)) as dependent variables. W is the number of wells including zeros. $D = 1$ if $W > 0$. An observation is a 1 km distance-bin in home country i, close to the border of neighbouring country j. $D = 1$ *rhs FH* takes one if country i has higher score on the augmented Freedom House political rights index than country j, and zero otherwise. Analogously, controls are dummies taking one if country i has the highest value on initial GDP per capita, previous drilling and country area size. Landlocked is a dummy taking one if country i is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. *Scaled L* is the coefficient on $D = 1$ *rhs FH* divided on *Mean L*. *Mean Y* is the sample-mean of the dependent variable. Models estimated with OLS. p-values in parenthesis are based on two-way clustering on country and border-region. Table B.7 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials. Figure B.7 in Online Appendix B presents the associated RD-graphs.

may be more of an issue for developing countries. Developing countries are also known to have more difficult business climates and more cumbersome bureaucracies.[35] We will now investigate how investors in oil exploration respond to institutional quality in developing countries and high income countries separately.

Table 8 presents the results. For developing countries, we estimate 156%–195% more drilling on the better side of the border (columns (1)–(4)), whereas the estimates are 88%–162% for high income countries (columns (5)–(8)). We conclude that the effect of institutional quality is present in both samples, as the coefficients are all positive and statistically significant at conventional levels. Comparing across the identical specifications, the effect in the high income sample is always smaller and

35. Harding and Javorcik (2011) find that investment promotion policies, which typically aim for alleviating frictions to foreign direct investments related to information asymmetries and red tape, are more effective in developing countries than in high income countries.

TABLE 8. Country heterogeneity.

	Developing countries				High income countries			
	W (1)	*W* (2)	*W* (3)	*W* (4)	*W* (5)	*W* (6)	*W* (7)	*W* (8)
$D = 1$ rhs FH	0.941	0.926	1.083	1.051	0.726	0.632	0.892	0.963
	(0.100)	(0.084)	(0.011)	(0.014)	(0.020)	(0.026)	(0.023)	(0.023)
$D = 1$ rhs GDPCAP		0.827	0.375	0.398		0.444	0.212	0.088
		(0.113)	(0.422)	(0.418)		(0.467)	(0.689)	(0.857)
$D = 1$ rhs Wpre66			1.776	1.358			1.459	1.202
			(0.000)	(0.000)			(0.000)	(0.002)
$D = 1$ rhs Area				0.347				0.575
				(0.436)				(0.089)
Landlocked				−1.887				−1.070
				(0.000)				(0.139)
Mean *L*	1.46	1.46	1.46	1.46	2.09	2.09	2.09	2.09
Observations	6179	6179	6179	6179	3337	3337	3337	3337
Countries	61	61	61	61	27	27	27	27
Neighbours	73	73	73	73	40	40	40	40
Clusters (iso)	61	61	61	61	27	27	27	27
Clusters (border2way)	97	97	97	97	51	51	51	51

Notes: Dependent variable is *W*, the number of wells including zeros. Columns (1)–(4) based on developing country sample, columns (5)–(8) based on high income country sample. An observation is a 1 km distance-bin in home country *i*, close to the border of neighbouring country *j*. $D = 1$ *rhs FH* takes one if country *i* has higher score on the augmented Freedom House political rights index than country *j*, and zero otherwise. Analogously, controls are dummies taking one if country *i* has the highest value on initial GDP per capita, previous drilling and country area size. Landlocked is a dummy taking one if country *i* is landlocked. *Mean L* is the within-sample mean of the dependent variable on the left hand side of the border. All columns estimated with Poisson maximum-likelihood. *p*-values in parentheses based on two-way clustering on country and border-region. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Table B.8 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials. Figure B.8 in Online Appendix B presents the associated RD-graphs.

vary from 7/10 to 9/10 of the developing country effect, with the smallest difference in the toughest specification (columns (4) and (8)).

5.3. *Heterogeneity across Investors*

Oil exploration is undertaken by a range of different types of companies, varying in scale, degree of vertical integration and model of ownership. Institutions may affect these companies differently if they face different objectives and constraints. For example, large publicly-traded companies may face high potential reputational costs. State owned companies may be insulated from political risk by their state backers or weigh noncommercial factors heavily. Small specialised exploration companies may be backed by risk-taking owners, such as hedge funds.

The group IOCs (International Oil Companies) are the so-called six supermajors (Chevron, Shell, BP, ExxonMobil, ConocoPhillips, and Total) and their subsidiaries and predecessors. They are international publicly-traded oil companies with predominantly nonstate ownership. They are vertically integrated by engaging in the entire industry value-chain, from exploration to production to downstream activities. NOCs (National Oil Companies) are typically set up to secure oil rents accruing to governments and to carry out national strategic objectives. Some of them operate outside of their home countries. OTHs (Others) is the group of remaining companies in our data, which include smaller specialised exploration companies who may seek to win licenses, engage in exploration and then transfer operations to more integrated companies. Anecdotal evidence suggests that the global oil industry recently moved towards less vertical integration and more outsourcing of high-risk exploration, at least before the financial crisis. Small and medium sized private international oil companies are likely to make a substantial share of OTH. Of the total of 23,000 wells we observe across developing and developed countries in our 75 km sample, IOCs, NOCs, and OTHs are listed as operators for 21.2%, 28.9%, and 49.9%, respectively.[36]

Table 9 presents estimates split up across different companies, for all countries (columns (1)–(4)), developing countries (columns (5)–(8)) and high income countries (columns (9)–(12)). The regressions include the same controls as before, included sequentially, and they take the same coefficients across company types. Company dummies are included in all regressions, but not shown to save space.[37] Just below these pooled regressions, we present *p*-values for tests of statistical differences across the coefficients on the institutions dummies and for a test of whether the coefficients are jointly zero per regression.

The striking insight from Table 9 is that IOCs are particularly sensitive to institutional quality in developing countries, whereas OTHs are particularly sensitive to institutional quality in high income countries. As seen from the row $p\ DIOC = DOTH$, the difference in the response of the two groups is statistically significant. From the estimated coefficients, we see that NOCs are an intermediate case in the two subsamples. For the full sample, we cannot reject that sensitivity to institutional quality is the same across the three company types. As seen in the last row, in all but two of the developing country sample regressions we can reject that the sensitivity to institutional quality is jointly zero. We conclude that exploration by all three company types is sensitive to institutional quality, but it matters most for IOCs in developing countries and OTHs in high income countries.

36. Many formerly state-owned oil companies have been privatised, particularly during the 1990s. For the analysis in this section we include in OTH those no longer under majority state-ownership in 2013. In all cases we look at the operating company only. Oil fields may be developed with multiple owners and minority participants, and ownership can change over time, especially moving from the exploration phase to the production phase. We thus limit our analysis to the well operator at the point of exploration only, as recorded in our data set. This excludes any examination of the role of nonoperator investors or those who may acquire a stake subsequent to exploration (which can sometimes apply to state-participation, where NOCs may acquire minority equity as part of the production phase).

37. Estimating instead entirely separate regressions for each company type gives similar results. We present the pooled results as we regard them as an intuitive and compact way of presenting the results.

TABLE 9. Investor heterogeneity.

	All countries				Developing countries				High income countries			
	W (1)	*W* (2)	*W* (3)	*W* (4)	*W* (5)	*W* (6)	*W* (7)	*W* (8)	*W* (9)	*W* (10)	*W* (11)	*W* (12)
$D=1$ rhs FH × IOC	0.935	0.855	1.054	1.035	1.730	1.696	1.838	1.810	−0.163	−0.252	0.033	0.090
	(0.190)	(0.213)	(0.117)	(0.132)	(0.086)	(0.078)	(0.039)	(0.044)	(0.628)	(0.433)	(0.938)	(0.843)
$D=1$ rhs FH × NOC	0.717	0.618	0.807	0.785	1.000	0.945	1.081	1.051	0.610	0.501	0.779	0.840
	(0.326)	(0.373)	(0.214)	(0.228)	(0.157)	(0.157)	(0.053)	(0.061)	(0.431)	(0.524)	(0.392)	(0.351)
$D=1$ rhs FH × OTH	1.018	0.950	1.147	1.132	0.480	0.469	0.614	0.585	1.039	0.948	1.227	1.298
	(0.000)	(0.000)	(0.000)	(0.000)	(0.181)	(0.181)	(0.047)	(0.073)	(0.002)	(0.002)	(0.002)	(0.002)
$D=1$ rhs GDPCAP		Yes	Yes	Yes		Yes	Yes	Yes		Yes	Yes	Yes
$D=1$ rhs Wpre66			Yes	Yes			Yes	Yes			Yes	Yes
$D=1$ rhs Area				Yes				Yes				Yes
Mean *L*	0.59	0.59	0.59	0.59	0.52	0.52	0.52	0.52	0.76	0.76	0.76	0.76
Observations	26295	26295	26295	26295	17020	17020	17020	17020	9275	9275	9275	9275
Countries	88	88	88	88	61	61	61	61	27	27	27	27
Neighbours	88	88	88	88	73	73	73	73	40	40	40	40
Clusters (iso)	88	88	88	88	61	61	61	61	27	27	27	27
Clusters (border2way)	130	130	130	130	97	97	97	97	51	51	51	51
p DIOC = DNOC	0.79	0.77	0.76	0.76	0.48	0.46	0.44	0.44	0.16	0.18	0.22	0.20
p DIOC = DOTH	0.89	0.88	0.88	0.88	0.07	0.08	0.08	0.08	0.00	0.00	0.00	0.00
p DNOC = DOTH	0.64	0.60	0.59	0.58	0.41	0.44	0.43	0.43	0.44	0.43	0.46	0.44
p DIOC = DNOC = DOTH = 0	0.00	0.00	0.00	0.00	0.20	0.22	0.06	0.08	0.00	0.00	0.00	0.00

Notes: Dependent variable is *W*, the number of wells including zeros. Columns (1)–(4) based on full sample, columns (5)–(8) on developing country sample, and columns (9)–(12) based on high income country sample. An observation is a 1 km distance-bin in home country *i*, close to the border of neighbouring country *j*. *W* is the number of wells including zeros. $D=1$ *rhs FH* takes one if country *i* has higher score on the augmented Freedom House political rights index than country *j*, and zero otherwise. See Table B.10 in Online Appendix B for the coefficients on the controls. All columns estimated with Poisson maximum-likelihood. *p*-values in parentheses based on two-way clustering on country and border-region. 75 km bandwidth and first order polynomial in distance to the border included separately on each side. Table B.9 in Online Appendix B shows this table also for 10 and 150 km bandwidths and zero and second order polynomials. Figure B.9 in Online Appendix B presents the associated RD-graphs.

6. Conclusions

A natural experiment of borders assigned independently of geology, together with predetermined institutions, allow identification of the responsiveness of oil exploration to the quality of institutions. Crossing a national border is found to generate a statistically and economically significant jump in oil and gas exploration drilling. All else equal, exploration companies prefer to drill on the side with the better democracy score more than two out of three times.

This paper contributes to the debate on the drivers of cross-country differences in economic performance. First, it shows that institutions have a strong effect on investments. Second, it reveals that the observed distribution of oil wealth across countries is endogenous. That is, also parts of the natural capital component of the "wealth of nations" respond to institutional quality. Regions such as sub-Saharan Africa may be "under-explored" with respect to geology alone, which can explain why they have found relatively little oil per square km. Third, for governments it is an important message that promising geology may not be sufficient to attract oil exploration. To the extent they can improve the institutional environment, they may accelerate discovery and increase their country's level of natural capital.

Appendix: Descriptive Statistics

TABLE A.1. Descriptive statistics.

	Count	p50	Mean	sd	Min	Max
			FH sample			
$D = 1$ rhs GDPCAP	9516	1	0.513	0.500	0	1
$D = 1$ rhs Wpre66	9516	0	0.432	0.495	0	1
$D = 1$ area	9516	1	0.524	0.499	0	1
Landlocked	9516	0	0.138	0.345	0	1
ΔFH	9516	0	0.00241	0.291	–0.873	0.873
FH	9516	0.717	0.682	0.266	0.102	1
Distance	9516	2	0.922	42.25	–75	75
W	9516	0	2.415	7.377	0	219
ln (W+1)	9516	0	0.558	0.911	0	5.394
$D = 1$	9516	0	0.365	0.481	0	1
ln W	3472	1.099	1.154	1.123	0	5.389
			Polity sample			
$D = 1$ rhs GDPCAP	7773	1	0.516	0.500	0	1
$D = 1$ rhs Wpre66	7773	0	0.490	0.500	0	1
$D = 1$ area	7773	1	0.569	0.495	0	1
Landlocked	7773	0	0.111	0.314	0	1
ΔPolity	7773	0	0.0434	7.782	–19	19
Polity	7773	2.200	1.472	6.951	–9	10
Distance	7773	7	4.707	42.41	–75	75
W	7773	0	2.838	7.990	0	219
ln (W+1)	7773	0	0.651	0.957	0	5.394
$D = 1$	7773	0	0.420	0.494	0	1
ln W	3264	1.099	1.184	1.119	0	5.389
			ANRR sample			
$D = 1$ rhs GDPCAP	2559	1	0.506	0.500	0	1
$D = 1$ rhs Wpre66	2559	1	0.511	0.500	0	1
$D = 1$ area	2559	1	0.563	0.496	0	1
Landlocked	2559	0	0.0473	0.212	0	1
ΔANRR	2559	–1	−0.00117	1.000	–1	1
ANRR	2559	0	0.499	0.500	0	1
Distance	2559	0	0.339	42.15	–75	75
W	2559	0	4.185	10.79	0	219
ln (W+1)	2559	0	0.837	1.080	0	5.394
$D = 1$	2559	0	0.499	0.500	0	1
ln W	1278	1.099	1.338	1.195	0	5.389

Notes: Based on full sample (defined in Section 2.1), 75 km distance from border. An observation is a 1 km distance-bin in home country i, close to the border of neighbouring country j.

TABLE A.2. Countries included in baseline sample (FH).

NO	IG	WBr	iso	Home obs.	Neighbour obs.	NO	IG	WBr	iso	Home obs.	Neighbour obs.
1	D	EAP	CHN	91	59	45	D	SSA	GAB	64	33
2	D	EAP	IDN	107	113	46	D	SSA	GHA	87	50
3	D	EAP	MMR	124	149	47	D	SSA	GIN	46	50
4	D	EAP	MYS	110	95	48	D	SSA	KEN	57	53
5	D	EAP	PHL	61	62	49	D	SSA	LBR	23	19
6	D	EAP	THA	145	143	50	D	SSA	MLI	235	215
7	D	ECA	TUR	178	152	51	D	SSA	MOZ	37	29
8	D	LAC	ARG	334	356	52	D	SSA	MRT	74	78
9	D	LAC	BOL	214	201	53	D	SSA	MWI	30	41
10	D	LAC	BRA	378	289	54	D	SSA	NER	223	186
11	D	LAC	CHL	76	112	55	D	SSA	NGA	199	124
12	D	LAC	COL	284	285	56	D	SSA	SLE	35	44
13	D	LAC	CRI	65	69	57	D	SSA	TCD	179	130
14	D	LAC	DOM	11	12	58	D	SSA	TGO	33	58
15	D	LAC	ECU	125	133	59	D	SSA	TZA	41	37
16	D	LAC	GTM	60	80	60	D	SSA	UGA	17	15
17	D	LAC	HND	46	41	61	D	SSA	ZMB	11	5
18	D	LAC	HTI	12	11	62	H	HI	AUS	219	213
19	D	LAC	JAM	21	14	63	H	HI	AUT	46	65
20	D	LAC	MEX	145	121	64	H	HI	BEL	1	26
21	D	LAC	NIC	111	115	65	H	HI	BRB	23	26
22	D	LAC	PAN	71	77	66	H	HI	CAN	152	150
23	D	LAC	PER	217	206	67	H	HI	CHE	33	98
24	D	LAC	PRY	164	196	68	H	HI	CYP	89	84
25	D	LAC	SLV	31	33	69	H	HI	DEU	201	228
26	D	LAC	URY	117	121	70	H	HI	DNK	256	236
27	D	LAC	VEN	137	135	71	H	HI	ESP	269	245
28	D	MENA	DZA	293	331	72	H	HI	FRA	380	340
29	D	MENA	EGY	65	51	73	H	HI	GBR	315	307
30	D	MENA	JOR	45	37	74	H	HI	GRC	126	146
31	D	MENA	MAR	135	119	75	H	HI	IRL	76	65
32	D	MENA	SYR	74	106	76	H	HI	ISL	23	50
33	D	MENA	TUN	138	140	77	H	HI	ISR	25	35
34	D	SA	IND	173	130	78	H	HI	ITA	284	205
35	D	SA	LKA	36	52	79	H	HI	JPN	39	50
36	D	SA	NPL	28	51	80	H	HI	KOR	76	92
37	D	SSA	BEN	55	92	81	H	HI	LUX	3	13
38	D	SSA	BFA	52	79	82	H	HI	NLD	134	130
39	D	SSA	CAF	58	78	83	H	HI	NOR	145	105
40	D	SSA	CIV	31	44	84	H	HI	NZL	74	76
41	D	SSA	CMR	59	149	85	H	HI	PRT	58	74
42	D	SSA	COD	15	17	86	H	HI	SWE	51	75
43	D	SSA	COG	75	84	87	H	HI	TTO	87	92
44	D	SSA	ETH	21	32	88	H	HI	USA	152	151
Total, developing countries				*6179*	*6139*	*Total, high income countries*				*3337*	*3377*
Grand total										*9516*	*9516*

Notes: Table presents the number of observations for home and neighbouring countries in the baseline sample (defined in Section 2.1). An observation is a 1 km distance-bin in home country i, close to the border of neighbouring country j. NO is a count, IG is income group, WBr is World Bank region and iso is the country code. Sums presented in last row.

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Supplementary Material

Supplementary data are available at *JEEA* online.