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Fossil fuel dependence and energy insecurity

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Abstract

Background: Access to reliable energy services is increasingly seen as a prerequisite for well-being and human development. Copious research documents the negative consequences that occur when nations specialize in natural resource production, creating a "natural resource curse" or "paradox of plenty". In this analysis, we evaluate how natural resource dependence, measured as oil and gas production, impacts energy security.

Results: Using entropy-balanced fixed effects models, we find that oil and coal production is not associated with shorter times to establish a connection to the electricity grid, fewer outages, or improve electricity access among the population.

Conclusions: Nations that produce oil and coal do not seem to have better energy insecurity as a result, representing a distributional inequality. Fossil fuel-producing nations should consider implementing policies that would allow them to retain more wealth from fossil fuel production.

Keywords: Energy, Development, Energy insecurity, Natural resource curse

Background

In an oft-cited quote, Schumacher (1982) noted that energy is "not just another commodity, but the precondition of all commodities, a basic factor equal with air, water, and earth" [1]. Access to energy services is recognized as a fundamental prerequisite for human flourishing and maximization of capabilities [2–4], although the degree of energy consumption in many developed nations far exceeds levels needed to maximize well-being [5–8]. More recent literature has centered energy security, or conversely, energy insecurity, as a key topic for scholars working at the linkage of well-being, development, sustainability, and the energy system. Indeed, the United Nations seventh sustainable development goal is to "Ensure access to affordable, reliable, sustainable and modern energy" [9].

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Energy insecurity can occur at both a system and a household scale. An energy system is thought to be insecure if it cannot provide consistent, affordable, reliable and sustainable energy services to those who need it [10–13]. At the household level, households are energy secure if they have reliable access to adequate energy services to provide for thermal comfort, reading light, and other needs [13, 14]. Importantly, household energy insecurity has been connected to a variety of negative health outcomes [15–19].

A long line of scholarship documents the deleterious consequences of natural resource dependence at multiple scales of analysis. At the international scale, nations that build their economies around natural resource extraction—such as mining or forestry—typically have slower economic growth, worse population health outcomes, and are more likely to have authoritarian governments. [2, 20–23]. Indeed, some authors refer to a "paradox of plenty" or "natural resource curse" to describe this phenomenon [24, 25]. Notably, the natural resource curse appears to persist at subnational scales also, such as within the U.S. or Canada [21, 26].

In this analysis, we ask the following research question: Is natural resource dependence related to energy insecurity at the country scale? To the best of our knowledge, this is the first study to evaluate this linkage. This is an important gap in our knowledge because, from an energy justice perspective, nations that produce rely upon fossil fuel production may not experience better energy security as a result. We suggest that natural resource dependence could be coupled with energy insecurity through a variety of mechanisms. For instance, natural resource dependence involves an inherent volatility that many not allow governments to collect consistent revenue that can be reinvested into electric grid infrastructure. Further, the political authoritarianism associated with natural resource dependence may create political incentives for authoritarian regimes that do not encourage improving energy security for its populations. In the next section, we describe the relevant literature on energy insecurity.

Energy insecurity

The origins of the concept of energy insecurity are diverse, and some researchers have used terms like "fuel poverty" to describe much the same issue. Energy systems that seem ostensibly secure at a macro-scale may still not provide an equitable distribution of energy services. For instance, several studies in some of the world's most affluent nations find evidence of significant energy insecurity at the household scale, which in turn has deleterious consequences on individuals in those households. Energy insecurity is a mediating mechanism between socio-economic status and health outcomes—that is, low-socio-economic status households often struggle to attain needed energy services, which in turn has negative health consequences [13]. Using French data, [17] and [18] find that energy insecurity is associated with lower self-rated health, these findings were echoed by [19]. Using a sample from a low-income neighborhood in a major metropolitan region of the U.S., [16] find that energy insecurity is associated with lower self-rated health, sleep problems, depression, and asthma. Also studying a metropolitan area in the U.S., [15] connect energy insecurity problem behaviors in children. Several studies have connected issues like lack of thermal comfort, drafty and cold buildings, and potential intermittency to various indicators of well-being, such as self-rated health [12, 16, 17, 19], asthma, depression and sleep problems [16], increased youth hospitalizations [15] and excess mortality during cold months [27].

Energy insecurity has increasingly been recognized as a barrier to human development and flourishing in low- and middle-income nations. The challenges created by energy insecurity are diverse and often context specific. For instance, inadequate electric grids create household reliance on stoves that burn combustible fuels like wood—these stoves are a fire hazard and the smoke that they create endangers the health of women who often perform cooking duties [28–30]. The poor indoor air quality engendered by cook stoves is also a threat to the health of children and the elderly [31]. Lack of reliable lighting at night can make it difficult for children to study at night, and lack of electricity is likely a contributor to illiteracy and low formal education [32–34]. In Ghana and Nigeria, energy-insecure households forgo basic necessities to pay for energy and their children are more likely to miss school days [14] Access to electricity is essential for the development of firms and effective institutions. Electricity allows for households to start businesses or otherwise engage in activities that generate employment and income [33, 35, 36].

Natural resource dependence

Natural resource dependence can occur when a bounded economy (at local, regional or even national scales) has its economic development primarily drive by extraction or production of natural resources, such as fossil fuels, minerals and related activities [37, 38]. Natural resource dependence is associated with a wide range of undesirable social and economic outcomes, although there is some variation in these relationships across contexts. Auty [2] coined the term "resource curse", observing that, counter to conventional economic theory (e.g., [39]), nations that were blessed with ample resource endowments tended to have significantly slower economic growth than nations without a rich abundance of natural resources. Freudenberg described communities with "resource addiction", whose economy was largely centered around unstable and ultimately unsustainable extractive activities [40, 41].

Auty [2] considered oil-producing nations and their industrial and fiscal policies. They argue that oil-rich nations often suffer due to the inherent instability of commodity prices and that, in many nations, foreign interests own or have significant influence on oil extraction. This causes a situation wherein oil-producing nations are unable to retain and reinvest much of the wealth generated from oil. Volatility is a common theme in the resource curse literature, and certainly one explanation for why resource-rich nations (or subnational regions) lag behind their less resource-rich counterparts [42].

Political factors also play a role in fomenting a "natural resource curse" scenario. Resource-rich nations tend to have authoritarian governments, or at least lack full democratization and struggle with problems of corruption [43, 44]. To some degree, this emerges because various political interests seek to develop a natural resource as quickly as quickly and cheaply as possible—Lane and Tornell [45] call this a "feeding frenzy". However, the causal relationship between natural resource dependence and governing regimes is complex. For instance, Bulte and Damiana [20] argue that corruption and lack of political allow for rent-seeking firms to encourage extractive activities that bolster their profits at the expense of the well-being of the nation. However, Brooks and Kurtz [46] suggest that natural resources—in their application, oil production—is *endogenous* to industrialization and democratization, in part because industrialized and democratic regimes are more apt to invest in the technologies and human capital necessary for oil resource development. The literature has not converged on a simple consensus on the link between natural resource dependence and democratization.

At the subnational scale, the evidence for a resource curse appears to be less ambiguous. For instance, a long line of studies conducted in the U.S. has connected mining activities to slow economic growth and poor performance on other socio-economic indicators [21, 22, 47–52]. For instance, James and Aadland [21] evaluated natural resource dependence (operationalized as the number of jobs in resource-related occupations) and economic performance for U.S. counties, ultimately concluding that resource-dependent counties had much slower economic growth. Considering 207 counties in the Western region of the U.S., Haggerty et al. [26] find that economic specialization in oil and gas development was associated with anemic economic development and social problems like crime. Natural resource curse dynamics have also been observed in mining regions of Australia [53, 54], and Canada [55]. Presumably, problems of natural resource dependence might exist in some regions of nation that are not writ large subject to the natural resource curse, while the natural resource curse can be observed cross-sectionally between nations.

The resource curse can be conceptualized in energy justice terms. Energy justice scholarship borrows from a range of empirical and theoretical perspectives and highlights questions of who benefits and who suffers from energy production [56–58]. Some regions serve as "sacrifice zones" for other places, absorbing the ill environmental and health effects of fossil fuel development while often receiving limited direct benefits [59–61]. Energy insecurity at the national scale can be viewed via the lens of energy justice. If a nation is producing fossils but their own energy security does not improve as a result, this situation is a distributional injustice.

Linking energy insecurity and the natural resource curse

We are unaware of any studies that have connected, either theoretically or empirically, natural resource dependence and energy insecurity at the national or subnational scale. Here, we suggest several mechanisms that might connect the two. Natural resource dependence might create a situation where energy-producing resources are sent abroad. These problems could be exacerbated in authoritarian regimes, whose tenuous grip on power might require that they sell off natural resources to gain the favor of a small economic elite [22, 23]. Further, as many scholars have noted, price volatility is an unavoidable part of extractive-based economies [40, 42]. This price volatility may create a situation wherein states, even democratic states, cannot effectively invest in long-run infrastructure development, such as improving the electric grid. Given the centrality of energy services for economic and human development, this lack of investment might create worse social and economic outcomes in the long run. Energy insecurity could be another mechanism by which natural resource dependence reduces the long-run fortunes of nations, or the well-being of their populations, but this relationship has undergone remarkably little evaluation. In the next section, we describe the data we use to connect natural resource dependence to energy insecurity at the national scale.

Methods

Outcome measures

We use several dependent variables. The first is a measure of the percentage of the population that has access to electricity. The IEA's 2009 report uses this variable as part of an index [62]. To some extent, access to electricity is not a direct measurement of energy insecurity as some energy systems may have ample access, but said access might be intermittent, unreliable, or otherwise insufficient. However, access to electricity is a useful indicator for two reasons. First, and most practically, this data is available for a wide cross-section of nations. More conceptually, access to electricity is a *prerequisite* for energy security. That is, an energy system cannot be secure if it does not provide access to electricity for large sections of its relevant population.

The final two variables have significantly less data available and are compiled from the World Bank's individual-country surveys. The first is a measure of the number of days that are typically required to establish a new electric connection. The second is a measure of the percentage of firms that have experienced a power outage within the last month. We provide the distribution of all three of these outcome measures in Fig. 1.

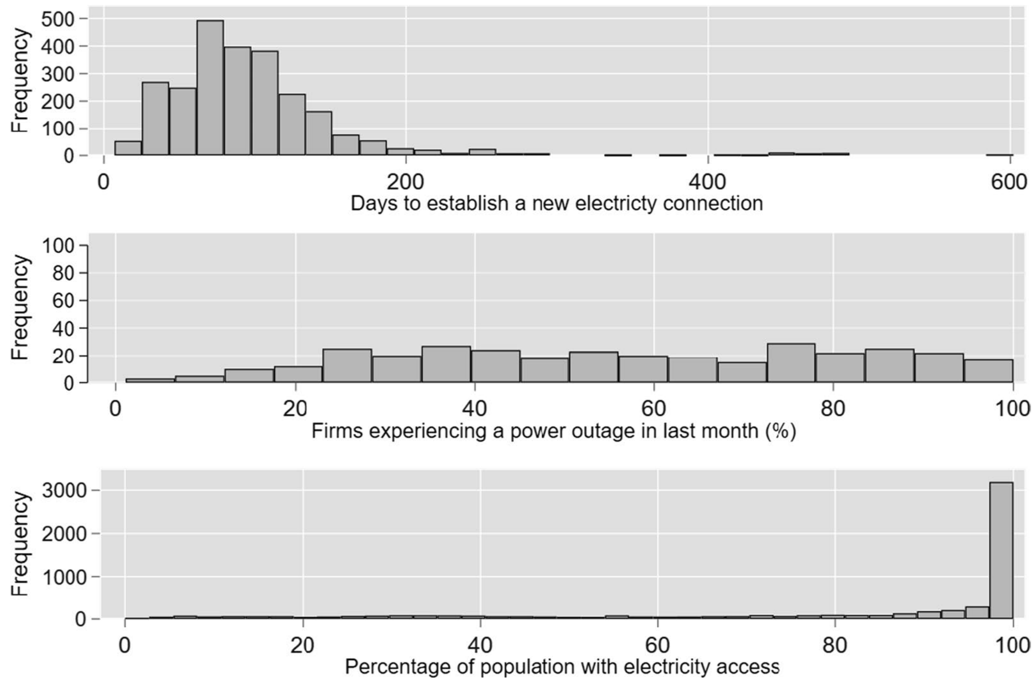

Fig. 1 Distribution of days to establish an electricity connection, the percentage of firms experiencing an outage in the last month, and the percentage of population with electricity access

Predictors:

Natural resource dependence has been measured in a variety of ways. Because the focus of our paper is energy-producing resources—specifically fossil fuels—we rely on indicators of the economic rents as a percentage of GDP produced by the oil and coal sector in each nation, again from data available on the World Bank data repository [63]. The World Bank calculates economic rents as the difference between the average cost of producing a commodity and the price of that commodity. We also include a binary variable for whether the nation was a producer of coal or oil—we calculated this variable by access oil and coal production data from BP's Statistical Review of World Energy [64]. We adopted this strategy of using a binary indicator of production because the oil and coal rents variables are highly skewed, and this allows us to ascertain the effect of simply hosting coal or oil production.

Control variables

Energy insecurity is likely influenced by a range of variables at the national scale. To mitigate against potential omitted variable bias, we employ a range of control variables, some of which are also entered into the entropy balancing algorithm (described further below). From the World Bank data repository, we access variables for GDP per capita in current USD, military expenditures as a percentage of GDP, and the percentage of a given nations population that lives in a rural area. We include GDP per capita because of the strong relationship between economic development and energy systems. Several studies find that nations that invest significant resources in their military have a range of worse environmental and social outcomes [65–67]. In our case, we might expect that public investment in militarization might crowd out investment in energy infrastructure, contributing to energy insecurity. We include the percentage of population that lives in a rural area because rural populations are typically more difficult to connect to electricity grids.

Earlier we noted an often-observed linkage between natural resource dependency and authoritarian regimes. There are several ways to operationalize democracy using well-vetted indicators. We opt to use the indicators provided by the Varieties of Democracy project [68]. We turn to this data set because it includes a measure of corruption, which is especially appropriate for our analysis as corruption is associated with natural resource-dependent regimes. A second advantage of this dataset is that it has rich coverage during the time when the first two outcomes (that is, days to establish an electricity connection and the percentages of firms experiencing an outage). From the Varieties of Democracy, we borrow the electoral democracy and corruption index. Table 1 displays descriptive statistics for all variables, and Appendix lists the countries included for each outcome variable.

Table 1 Descriptive statistics for predictor variables

Variable	Description	Mean	Std. Dev
Oil Rents	Oil rents as a percentage of GDP	3.523	9.17
Coal rents	Coal rents as a percentage of GDP	0.169	1.004
Oil production	0 = no production, 1 = production	0.289	0.454
Coal production	0 = no production, 1 = production	0.257	0.437
Rural Population(%)	Rural population (% of total population)	41.788	22.675
Electoral Democracy	Electoral democracy (varieties of democracy)	0.547	0.248
Corruption	Corruption (varieties of Democracy)	0.49	0.302
GDP per capita ($000)	GDP per capita in thousands of USD	13.802	19.56
Population(00,000)	Population in 10000 s	34.401	124.291
Military Exp(% GDP)	Military Expenditures as a % of GDP	6.352	5.432

Note: Descriptive statistics were calculated using the estimation sample from Model 3, Table 2. Data were derived from the World Bank database, the BP Statistical Review of World Energy and Varieties of Democracy Project

Modeling approach

Our indicators of energy security are very different and require different modeling strategies. Access to electricity and number of days required to make a electricity connection has thousands of observations across many countries and years. For these indicators, we opt for a panel regression model with country fixed effects. The sample sizes for firm outages and the number of days required is much sparser. For firm outages, there are 366 observations spread between 2006–2019, with many countries having only a single observation. For this indicator, we eschew the country fixed effects.

We also take additional steps to improve causal inference for each model. We use Tubbike's [69] recent extension of the entropy balancing method for continuous treatments. The original entropy balancing method was developed by [70] and [71]. Entropy balancing is somewhat akin to other causal inference techniques like propensity score matching, in that it seeks to create covariate balance between treatment and control groups. Entropy balancing accomplishes these through a data-preprocessing, algorithmic procedure that generates weights that balance covariates on sample moments specified by the analyst. Often, entropy balancing is used to balance on means and standard deviations, creating statistical equivalence between treatment and control groups for the covariates chosen by the research. In this way, the binary case of entropy balancing mimics random assignment with respect to the covariates chosen by the researcher—it effectively mitigates the "selection on observables" problem in causal inference. Entropy balancing has many attractive advantages over more established methods like propensity score matching in that it eliminates many of the rather arbitrary choices made by researchers in developing a matching model. However, its limitation is that it only accommodates binary treatments.

Tubbike [69] developed a powerful extension of entropy balancing that allows for the use of continuous treatment—entropy balancing for continuous treatments, of EBCT. Tubbike [69] explains that "Essentially, EBCT re-weights all units to achieve zero correlations between the treatment variable and covariates." (p.8). This is akin to a situation wherein the treatment variable was randomly assigned with respect to potential confounders. In our application, we use EBCT to mimic a situation wherein natural resource dependence (in our case, oil and coal rents) is randomly distributed with respect to GDP per capita, population, rural population (%), and political variables for electricity access and days required to receive a new electricity hookup. The outages data are sparser and cannot be balanced on the full range of covariates without losing significant data points due to list-wise deletion. Accordingly, we balance on GDP per capita, population size, and the percentage of rural population for this variable and eschew adding a full suite of predictors in our regression equations.

Our measures of days to establish an electricity connection is highly skewed and over-dispersed—that is, the variance far exceeds the mean. In these instances, conventional regression models (e.g., OLS) will produce biased estimates. To avoid these problems, we estimate the models for days to establish an electricity connection and the percentages of outages using negative binomial regression, an appropriate model for over-dispersed count data [72]. The data for firm outages and electricity access is not over-dispersed. Thus, we employ a more conventional OLS model for this variable.

Oil rents results

Table 2 displays coefficients, standard errors, and R^2 statistics for our oil rents models. Model 2 implies that oil rents have no direct influence on the days to establish a new energy connection (b = -0.61, n.s.). Indeed, few variables—except for population size—emerge as statistically significant in this model. Model 2 uses the percentage of firms

Table 2 Negative binomial and OLS regression models for energy insecurity

		Oil dependency			Coal dependency	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	Days for electricity	**Firm outages (%)**	**Electricity access (%)**	**Days for electricity**	**Firm outages (%)**	**Electricity access (%)**
Variable name						
Oil rents(% GDP)	− 0.00	0.01	0.16*	–	–	–
	(0.00)	(0.46)	(0.07)	–	–	–
Oil production dummy	0.11	− 4.29	0.77	–	–	–
	(0.08)	(4.21)	(1.25)	–	–	–
Coal rents (% GDP)	–	–	–	0.01	− 2.16*	− 0.02
	–	–	–	(0.01)	(1.07)	(0.24)
Coal production dummy	–	–	–	0.07	− 7.30*	− 7.64**
	–	–	–	(0.05)	(3.18)	(1.91)
Population(00,000)	− 0.01*	− 0.01	0.05**	− 0.01	0.02	0.17**
	(0.00)	(0.01)	(0.01)	(0.00)	(0.04)	(0.04)
Rural population(% total)	0.00	0.32**	− 0.63**	0.01*	0.33**	− 1.24**
	(0.01)	(0.11)	(0.06)	(0.01)	(0.10)	(0.06)
Electoral democracy	− 0.08	19.06	− 1.08	− 0.05	22.74*	− 4.29
	(0.09)	(9.78)	(2.16)	(0.09)	(11.51)	(2.56)
Corruption	0.12	13.80	− 8.71**	0.22	13.86	− 16.05**
	(0.18)	(8.47)	(2.37)	(0.16)	(8.75)	(2.58)
GDP per cap ($000)	− 0.00	− 1.55**	− 0.25**	− 0.00	− 1.46**	− 0.14**
	(0.00)	(0.33)	(0.03)	(0.00)	(0.31)	(0.01)
Military (% GDP)	0.00	–	− 0.18**	− 0.00	–	− 0.29**
	(0.01)	–	(0.06)	(0.00)	–	(0.05)
McFadden R^2	0.244	–	–	0.237	–	–
R^2	–	0.29	0.97	–	0.37	0.97
N	1407	235	3280	1551	215	3280

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$. Models 1 and 4 use negative binomial regression, all other models use OLS. Models 1, 3, 4 and 6 include country fixed effects. All models include an unreported year term and entropy balancing weights

experiencing an outage in the last month as the dependent variable. This model drops military expenditure per capita as a predictor and eschews the country fixed effects due to the relatively small sample size. Here again, we find that oil rents do not improve or damage this measure of energy insecurity. Finally, we turn our attention to Model 3. Here, we find that oil rents are associated with increased energy access ($b = 0.16$, $p < 0.05$). Population size is associated with increased electricity access, and access declines as rural populations increase, and military expenditures grow.

Coal rents results

For coal rents, we first consider Model 4, which uses days to establish an electricity connection as the outcome variable and includes the entropy balancing weights. Here we find that coal rents and coal production do not have a statistically significant effect on the days to establish an electricity connection. Model 5 suggests that as coal rents increase, the percentage of firms experiencing outages declines, the dummy variable for coal production has a similar negative effect. In model 6, the effect of coal rents is not significant, but coal-producing nations have lower electricity access.

Konfound analysis

We conducted additional checks to determine the relative robustness of our results. We implement the *konfound* method [73, 74]. Analysts often evaluate robustness by estimating models with proxy variables or different model specifications in a somewhat arbitrary fashion. The advantage of *konfound* is that it estimates a percentage of cases that would have to be replaced to invalidate an inferences—that is, to render a non-significant result significant or vice versa. For linear models (e.g., OLS), *konfound* also estimates the correlation between the predictor and outcome that would be necessary to change the inference. Please note that, in our applications, this correlation coefficient cannot be estimated for our negative binomial models—*konfound* cannot yet estimate the correlation threshold for non-linear models (i.e., models 1 and 4).

The konfound analysis (Table 3) suggests that the null results for firm outages in model 2 are uniquely robust, with

Table 3 Results of konfound analysis

	Model 1	Model 2		Model 3		Model 4	Model 5		Model 6	
	%	%	Correlation	%	Correlation	%	%	Correlation	%	Correlation
Oil rents	14.74	98.69	0.337	15.14%	0.081	–	–	–	–	–
oil production	28.98	48.31	0.23	68.62%	0.153	–	–	–	–	–
Coal Rents	–	–	–	–	–	10.88	1.90	0.055	96.14	0.181
Coal Production	–	–	–	–	–	60.01	14.04	0.159	50.88	0.194

Note: Table reports the percentage of cases that would have to be replaced to change the inference and the absolute value of the correlation between and omitted predictor and outcome to invalidate the inference

a very high degree of misclassification (98.69%) necessary to make the effect of oil rents statistically significant. For model 3, the statistically significant effect of oil rents could be invalidated if 15.14% of the cases were misclassified and an omitted variable was correlated at 0.081 with oil rents and -0.081 with electricity access, implying that this result may be more brittle than others. However, there are likely few omitted variables having a positive correlation with oil rents and a negative relationship with electricity access. Similarly, the statistically significant effect of coal rent on firm outages on Model 5 would become non-significant if only 1.9% of the cases were misclassified, and the correlation to invalidate the inference is 0.055. Finally, the results for model 6, wherein our binary variable for coal production was statistically significant, appear to be relatively robust. Overall, the konfound analysis implies that the few statistically significant effects could be rendered non-significant with relatively modest changes in model specification.

Discussion

The purpose of this paper is to understand the effect of natural resource dependence—specifically, dependence upon fossil fuel production—on indicators of energy insecurity. Scholarship has increasing foregrounded energy security as an important factor in economic development, well-being and livelihoods [12, 13]. Further, energy justice scholarship foregrounds concerns about who benefits and who suffers from energy production [58]. Although the deleterious consequences of natural resource dependence are well-documented [2], it is not well-understood if fossil fuel production improves or damages energy security at the national scale. In this section, we discuss our findings considering the conceptual framework detailed earlier in the paper.

Generally, our indicators of natural resource dependence had effects that were not statistically significant. We recognize that many scholars implicitly or explicitly view statistically significant results as more "interesting" in some ways, and perhaps may view analyses that produce statistically non-significant results as somehow flawed or in error. Of course, many leading methodologists have challenged the long tradition in the sciences of foregrounding p-values as the centerpiece of a given analysis and some journals and disciplines have followed suit by banning p-values or encouraging other ways to assess findings [75–78]. We do not seek to wade into these debates, we only point out that there are important reasons why scholars should recognize that null findings are, in fact, informative.

In the current paper, the mostly null effects of our indicators for oil and coal dependence have practical and theoretical implications. Our models imply that, across multiple indicators of energy insecurity, the production of fossil fuels did not appear to consistently increase or improve energy security within the nations under study. This was especially true for oil production, although coal production had more nuanced effects. This analysis implies that the production of fossil fuels does not necessarily engender "natural resource curse" dynamics wherein a nation's population is more energy insecurity because of fossil fuel production. However, our analysis does illustrate a distributional inequality—nations that are producing fossil fuels do not see improvements in their energy systems, at least in terms of energy insecurity. From an energy justice perspective, this is a uniquely substantive finding. Nations that specialize in fossil fuel production do not necessarily experience a "curse" with regard to energy insecurity but are in the seemingly paradoxical situation where their energy production does not enhance their own energy security. Our results imply that fossil fuel-producing nations could implement policies to retain and redistribute more of the benefits of their production.

We suggest that more empirical and theoretical work is needed to unpack a middle ground between an optimistic account of fossil fuels that paints them as a driver of broadly shared benefits and the prototypical natural resource curses scenario, wherein nations perform more poorly a broad swath of social and economic indicators because of fossil fuels. Understanding how fossil fuel production does not translate into greater energy security is a needed task for future research.[1] A limitation of this study is our use of country-level data—we cannot evaluate within-country differences in natural resource dependence and energy insecurity.

[1] The null effects of the entropy balanced predictors are partially a result of the entropy balancing, which reweights to remove the correlation between these covariates and the outcomes.

National subregions that specialize in resource production may suffer from problems of energy insecurity.

An important caveat is that our modeling strategy is uniquely robust to issues of omitted variable bias and statistical non-equivalence among confounders because we employ a combination of entropy balancing and fixed effects. This means that, barring the effect of some unmeasured confounder, our estimates of the effect of natural resource dependency represent a robust direct effect of these variables. However, we did not model the indirect effects of oil and coal dependence. That is, perhaps oil and gas dependence is a distal cause of social and economic maladies. Further, we did not allow the effect of oil and coal dependence to vary across nations—as we noted in our literature review, there is evidence that natural resource curse dynamics can occur at a subnational scale, implying that in some places become "cursed" while others do not experience profoundly deleterious outcomes. Further, we remind that reader that we only consider indicators related to energy insecurity, not a broad suite of social and economic variables. While energy insecurity is important, other research might find the oil and coal dependence, as operationalized here, might be associated with any number of undesirable social or economic consequences.

Conclusion

Nations that produce fossil fuels should ostensibly benefit in the form of improved energy insecurity. Yet our results suggest that this is not the case—nations that specialize in the production of fossil fuels typically do no better than their counterparts in providing a secure energy system for their populations. However, we do not observe a prototypical "resource curse" scenario wherein energy security is *worse* because of fossil fuel production. More work is needed to understand how nations or national subregions that specialize in resource production can use this wealth to improve services and infrastructure.

Appendix

See Table 4.

Table 4 Countries used in each model

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Afghanistan	Afghanistan	Afghanistan	Afghanistan	Afghanistan	Afghanistan
Albania	Albania	Albania	Albania	Albania	Albania
Algeria	Angola	Algeria	Algeria	Angola	Algeria
Angola	Antigua and Barbuda	Angola	Angola	Antigua and Barbuda	Angola
Argentina	Argentina	Argentina	Argentina	Arab World	Argentina
Armenia	Armenia	Armenia	Armenia	Argentina	Armenia
Australia	Azerbaijan	Australia	Australia	Armenia	Australia
Austria	Bahamas, The	Austria	Austria	Azerbaijan	Austria
Azerbaijan	Bangladesh	Azerbaijan	Azerbaijan	Bahamas, The	Azerbaijan
Bahrain	Barbados	Bahrain	Bahrain	Bangladesh	Bahrain
Bangladesh	Belarus	Bangladesh	Bangladesh	Barbados	Bangladesh
Barbados	Belize	Barbados	Barbados	Belarus	Belarus
Belarus	Benin	Belarus	Belarus	Belize	Belgium
Belgium	Bhutan	Belgium	Belgium	Benin	Benin
Benin	Bolivia	Benin	Benin	Bhutan	Bolivia
Bhutan	Bosnia and Herzegovina	Bhutan	Bhutan	Bolivia	Bosnia and Herzegovina
Bolivia	Botswana	Bolivia	Bolivia	Bosnia and Herzegovina	Botswana
Bosnia and Herzegovina	Brazil	Bosnia and Herzegovina	Bosnia and Herzegovina	Botswana	Brazil
Botswana	Bulgaria	Botswana	Botswana	Brazil	Bulgaria
Brazil	Burkina Faso	Brazil	Brazil	Bulgaria	Burkina Faso
Bulgaria	Burundi	Bulgaria	Bulgaria	Burkina Faso	Burundi
Burkina Faso	Cabo Verde	Burkina Faso	Burkina Faso	Burundi	Cabo Verde
Burundi	Cambodia	Burundi	Burundi	Cabo Verde	Cambodia
Cabo Verde	Cameroon	Cabo Verde	Cabo Verde	Cambodia	Cameroon
Cambodia	Central African Republic	Cambodia	Cambodia	Cameroon	Canada
Cameroon	Chad	Cameroon	Cameroon	Caribbean small states	Central African Republic
Canada	Chile	Canada	Canada	Central African Republic	Chad
Central African Republic	China	Central African Republic	Central African Republic	Chad	Chile

Table 4 (continued)

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Chad	Colombia	Chad	Chad	Chile	China
Chile	Congo, Dem Rep	Chile	Chile	China	Colombia
China	Congo, Rep	China	China	Colombia	Congo, Dem Rep
Colombia	Costa Rica	Colombia	Colombia	Congo, Dem Rep	Congo, Rep
Comoros	Cote d'Ivoire	Comoros	Comoros	Congo, Rep	Costa Rica
Congo, Dem Rep	Croatia	Congo, Dem Rep	Congo, Dem Rep	Costa Rica	Cote d'Ivoire
Congo, Rep	Czech Republic	Congo, Rep	Congo, Rep	Cote d'Ivoire	Croatia
Costa Rica	Djibouti	Costa Rica	Costa Rica	Croatia	Cyprus
Cote d'Ivoire	Dominica	Cote d'Ivoire	Cote d'Ivoire	Cyprus	Czech Republic
Croatia	Dominican Republic	Croatia	Croatia	Czech Republic	Denmark
Cyprus	Ecuador	Cuba	Cyprus	Djibouti	Djibouti
Czech Republic	Egypt, Arab Rep	Cyprus	Czech Republic	Dominica	Dominican Republic
Denmark	El Salvador	Czech Republic	Denmark	Dominican Republic	Ecuador
Djibouti	Eritrea	Denmark	Djibouti	Early-demographic dividend	Egypt, Arab Rep
Dominican Republic	Estonia	Djibouti	Dominican Republic	Ecuador	El Salvador
Ecuador	Eswatini	Dominican Republic	Ecuador	Egypt, Arab Rep	Equatorial Guinea
Egypt, Arab Rep	Ethiopia	Ecuador	Egypt, Arab Rep	El Salvador	Eritrea
El Salvador	Fiji	Egypt, Arab Rep	El Salvador	Eritrea	Estonia
Equatorial Guinea	Gabon	El Salvador	Equatorial Guinea	Estonia	Eswatini
Eritrea	Gambia, The	Equatorial Guinea	Eritrea	Eswatini	Ethiopia
Estonia	Georgia	Eritrea	Estonia	Ethiopia	Fiji
Eswatini	Ghana	Estonia	Eswatini	Fiji	Finland
Ethiopia	Greece	Eswatini	Ethiopia	Gabon	France
Fiji	Grenada	Ethiopia	Fiji	Gambia, The	Gabon
Finland	Guatemala	Fiji	Finland	Georgia	Gambia, The
France	Guinea	Finland	France	Ghana	Georgia
Gabon	Guinea-Bissau	France	Gabon	Greece	Germany
Gambia, The	Guyana	Gabon	Gambia, The	Grenada	Ghana
Georgia	Honduras	Gambia, The	Georgia	Guatemala	Greece
Germany	Hungary	Georgia	Germany	Guinea	Guatemala
Ghana	India	Germany	Ghana	Guinea-Bissau	Guinea
Greece	Indonesia	Ghana	Greece	Guyana	Guinea-Bissau
Guatemala	Iraq	Greece	Guatemala	Honduras	Guyana
Guinea	Israel	Guatemala	Guinea	Hungary	Haiti
Guinea-Bissau	Jamaica	Guinea	Guinea-Bissau	India	Honduras
Guyana	Jordan	Guinea-Bissau	Guyana	Indonesia	Hungary
Haiti	Kazakhstan	Guyana	Haiti	Iraq	Iceland
Honduras	Kenya	Haiti	Honduras	Israel	India
Hong Kong SAR, China	Kyrgyz Republic	Honduras	Hong Kong SAR, China	Italy	Indonesia
Hungary	Lao PDR	Hong Kong SAR, China	Hungary	Jamaica	Iran, Islamic Rep
Iceland	Latvia	Hungary	Iceland	Jordan	Iraq
India	Lebanon	Iceland	India	Kazakhstan	Ireland
Indonesia	Lesotho	India	Indonesia	Kenya	Israel
Iran, Islamic Rep	Liberia	Indonesia	Iran, Islamic Rep	Kyrgyz Republic	Italy
Iraq	Lithuania	Iran, Islamic Rep	Iraq	Lao PDR	Jamaica
Ireland	Madagascar	Iraq	Ireland	Latvia	Japan
Israel	Malawi	Ireland	Israel	Lebanon	Jordan
Italy	Malaysia	Israel	Italy	Lesotho	Kazakhstan
Jamaica	Mali	Italy	Jamaica	Liberia	Kenya
Japan	Mauritania	Jamaica	Japan	Lithuania	Korea, Rep
Jordan	Mauritius	Japan	Jordan	Madagascar	Kuwait
Kazakhstan	Mexico	Jordan	Kazakhstan	Malawi	Kyrgyz Republic

Table 4 (continued)

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Kenya	Moldova	Kazakhstan	Kenya	Malaysia	Lao PDR
Korea, Rep	Mongolia	Kenya	Korea, Rep	Mali	Latvia
Kuwait	Montenegro	Korea, Rep	Kuwait	Malta	Lebanon
Kyrgyz Republic	Morocco	Kuwait	Kyrgyz Republic	Mauritania	Lesotho
Lao PDR	Mozambique	Kyrgyz Republic	Lao PDR	Mauritius	Liberia
Latvia	Myanmar	Lao PDR	Latvia	Mexico	Libya
Lebanon	Namibia	Latvia	Lebanon	Moldova	Lithuania
Lesotho	Nepal	Lebanon	Lesotho	Mongolia	Luxembourg
Liberia	Nicaragua	Lesotho	Liberia	Montenegro	Madagascar
Libya	Niger	Liberia	Libya	Morocco	Malawi
Lithuania	Nigeria	Libya	Lithuania	Mozambique	Malaysia
Luxembourg	North Macedonia	Lithuania	Luxembourg	Myanmar	Mali
Madagascar	Pakistan	Luxembourg	Madagascar	Namibia	Malta
Malawi	Panama	Madagascar	Malawi	Nepal	Mauritania
Malaysia	Papua New Guinea	Malawi	Malaysia	Nicaragua	Mauritius
Maldives	Paraguay	Malaysia	Maldives	Niger	Mexico
Mali	Peru	Maldives	Mali	Nigeria	Moldova
Malta	Philippines	Mali	Malta	North Macedonia	Mongolia
Mauritius	Romania	Mauritania	Mauritius	Pakistan	Morocco
Mexico	Russian Federation	Mauritius	Mexico	Panama	Mozambique
Moldova	Rwanda	Mexico	Moldova	Papua New Guinea	Myanmar
Mongolia	Samoa	Moldova	Mongolia	Paraguay	Namibia
Montenegro	Senegal	Mongolia	Montenegro	Peru	Nepal
Morocco	Serbia	Montenegro	Morocco	Philippines	Netherlands
Mozambique	Sierra Leone	Morocco	Mozambique	Poland	New Zealand
Myanmar	Slovak Republic	Mozambique	Myanmar	Portugal	Nicaragua
Namibia	Slovenia	Myanmar	Namibia	Romania	Niger
Nepal	Solomon Islands	Namibia	Nepal	Russian Federation	Nigeria
Netherlands	South Africa	Nepal	Netherlands	Rwanda	North Macedonia
New Zealand	South Sudan	Netherlands	New Zealand	Samoa	Norway
Nicaragua	Sri Lanka	New Zealand	Nicaragua	Senegal	Oman
Niger	St Kitts and Nevis	Nicaragua	Niger	Serbia	Pakistan
Nigeria	St Lucia	Niger	Nigeria	Sierra Leone	Panama
North Macedonia	Vincent and the Grenadines	Nigeria	North Macedonia	Slovak Republic	Papua New Guinea
Norway	Sudan	North Macedonia	Norway	Slovenia	Paraguay
Oman	Suriname	Norway	Oman	Solomon Islands	Peru
Pakistan	Tajikistan	Oman	Pakistan	South Africa	Philippines
Panama	Tanzania	Pakistan	Panama	South Asia	Poland
Papua New Guinea	Thailand	Panama	Papua New Guinea	South Asia (IDA and IBRD)	Portugal
Paraguay	Togo	Papua New Guinea	Paraguay	South Sudan	Qatar
Peru	Tonga	Paraguay	Peru	Sri Lanka	Romania
Philippines	Trinidad and Tobago	Peru	Philippines	St Kitts and Nevis	Russian Federation
Poland	Tunisia	Philippines	Poland	St Lucia	Rwanda
Portugal	Turkey	Poland	Portugal	St Vincent and the Grenadines	Saudi Arabia
Qatar	Uganda	Portugal	Qatar	Sudan	Senegal
Romania	Ukraine	Qatar	Romania	Suriname	Serbia
Russian Federation	Uruguay	Romania	Russian Federation	Tajikistan	Seychelles
Rwanda	Uzbekistan	Russian Federation	Rwanda	Tanzania	Sierra Leone
Sao Tome and Principe	Vanuatu	Rwanda	Sao Tome and Principe	Thailand	Singapore
Saudi Arabia	Venezuela, RB	Sao Tome and Principe	Saudi Arabia	Timor-Leste	Slovak Republic
Senegal	Vietnam	Saudi Arabia	Senegal	Togo	Slovenia

Table 4 (continued)

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Serbia	West Bank and Gaza	Senegal	Serbia	Tonga	South Africa
Seychelles	Yemen, Rep	Serbia	Seychelles	Trinidad and Tobago	South Sudan
Sierra Leone	Zambia	Seychelles	Sierra Leone	Tunisia	Spain
Singapore	Zimbabwe	Sierra Leone	Singapore	Turkey	Sri Lanka
Slovak Republic		Singapore	Slovak Republic	Uganda	Sudan
Slovenia		Slovak Republic	Slovenia	Ukraine	Sweden
Solomon Islands		Slovenia	Solomon Islands	Uruguay	Switzerland
South Africa		Solomon Islands	South Africa	Uzbekistan	Syrian Arab Republic
South Sudan		South Africa	South Sudan	Vanuatu	Tajikistan
Spain		South Sudan	Spain	Venezuela, RB	Tanzania
Sri Lanka		Spain	Sri Lanka	Vietnam	Thailand
Sudan		Sri Lanka	Sudan	West Bank and Gaza	Timor-Leste
Suriname		Sudan	Suriname	Yemen, Rep	Togo
Sweden		Suriname	Sweden	Zambia	Trinidad and Tobago
Switzerland		Sweden	Switzerland	Zimbabwe	Tunisia
Tajikistan		Switzerland	Tajikistan		Turkey
Tanzania		Syrian Arab Republic	Tanzania		Uganda
Thailand		Tajikistan	Thailand		Ukraine
Timor-Leste		Tanzania	Timor-Leste		United Arab Emirates
Togo		Thailand	Togo		United Kingdom
Trinidad and Tobago		Timor-Leste	Trinidad and Tobago		United States
Tunisia		Togo	Tunisia		Uruguay
Turkey		Trinidad and Tobago	Turkey		Uzbekistan
Uganda		Tunisia	Uganda		Vietnam
Ukraine		Turkey	Ukraine		Yemen, Rep
United Arab Emirates		Turkmenistan	United Arab Emirates		Zambia
United Kingdom		Uganda	United Kingdom		Zimbabwe
United States		Ukraine	United States		
Uruguay		United Arab Emirates	Uruguay		
Uzbekistan		United Kingdom	Uzbekistan		
Vanuatu		United States	Vanuatu		
Venezuela, RB		Uruguay	Venezuela, RB		
Vietnam		Uzbekistan	Vietnam		
West Bank and Gaza		Vanuatu	West Bank and Gaza		
Yemen, Rep		Venezuela, RB	Yemen, Rep		
Zambia		Vietnam	Zambia		
Zimbabwe		West Bank and Gaza	Zimbabwe		
		Yemen, Rep			
		Zambia			
		Zimbabwe			

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