Energy Policy 126 (2019) 361–369

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Do natural resources impede renewable energy production in the EU? A mixed-methods analysis

Anar Kamil Ahmadov*, Charlotte van der Borg

University College The Hague, Faculty of Governance and Global Affairs, Leiden University, Anna van Buerenplein 301, 2595DG, The Hague, the Netherlands

ARTICLE INFO

Keywords:
European Union
Natural resources
Petroleum rents
Renewable energy

ABSTRACT

Since signing the Amsterdam Treaty in 1997, the European Union (EU) has been working on increasing its renewable energy supply. However, the progress has been uneven across member states. A vibrant literature advances several explanations for this variation, but pays insufficient attention to a critical structural factor – varying levels of natural resource wealth across the EU – and provides an incomplete account by focusing on consumption indicators. Reconciling divergent views in the literature in a single framework, we hold that while overall natural resource abundance can be conducive to renewable energy production within a country, specific natural resources, such as petroleum, are likely to be harmful. These hypotheses find empirical support in a mixed-methods study that combines a fixed-effects statistical analysis of comprehensive panel data between 1997 and 2015 with a comparative qualitative case study of the Netherlands and Belgium. The findings suggest that to achieve the ambitious goals on renewable energy deployment, the EU needs additional policies that explicitly tackle pernicious effects of specific natural resources, including rent-capturing by politicians, rent-seeking by corporate vested interests, and lack of economic incentives to diversify.

1. Introduction

Since signing the Amsterdam Treaty in 1997, the European Union (EU) has been working on increasing its renewable energy supply. A decade later the Renewables Directive set the goal of increasing the share of renewable energy in final energy consumption across the EU to 20 per cent by 2020 (European Commission, 2016). While the deployment of renewables in the EU has grown, the progress has been uneven across member states (Bürgin, 2015). A vibrant literature has advanced a number of explanations for this variation (for useful summaries, see Bürgin, 2015; Cadoret and Padovano, 2016; Strunz et al., 2015).

One critical factor that has been dealt with only indirectly is natural resource wealth. This creates a major gap in the literature. First, natural resource wealth varies considerably across the EU (see BP, 2017) but its direct impact on renewable energy is overlooked because existing work at best uses indirect proxy measures, such as energy dependence. Second, some factors that are believed to affect renewable energy deployment can themselves depend on natural resource wealth because the latter is often an exogenous, structural variable that has been shown to lead to economic underperformance and poor institutional quality (Bulte et al., 2005; Dunning, 2005; Ross, 1999). Therefore, omitting a direct measure of resource abundance from the analysis risks misattributing its effect to factors that transmit its impact. Tackling these secondary factors may be akin to addressing symptoms rather than underlying causes. Finally, discussions on the potential impact of natural resources on renewable energy deployment offer two conflicting arguments, but a framework that can reconcile these views while doing justice to both has not been proposed.

Building on the existing literature, we argue that while, on the one hand, overall natural resource wealth can be conducive to renewable energy production by providing required capital, on the other hand, specific natural resources, such as petroleum, are likely to be harmful due to their potentially corrosive effect on the economy and governance. Consequently, this paper pursues several objectives. The first is to offer a systematic empirical investigation of the effect of natural resource wealth on renewable energy across the EU since the 1997 Amsterdam Treaty till 2015. The second is to explore the processes through which this association is likely to be transmitted. Our overarching objective is to help advance European energy policy debates by casting light on what impact policies, governance, and other time-variant factors have on renewable energy production once the effects of all important variables, including natural resources, are duly accounted for in a unified framework. To these ends, we employ a mixed-methods research design that combines a fixed-effects panel data statistical analysis with a comparative qualitative case study of the Netherlands

* Corresponding author.
E-mail addresses: a.k.o.ahmadov@luc.leidenuniv.nl (A.K. Ahmadov), c.a.van.der.borg@umail.leidenuniv.nl (C. van der Borg).

https://doi.org/10.1016/j.enpol.2018.11.044
Received 12 January 2018; Received in revised form 3 October 2018; Accepted 21 November 2018
Available online 28 November 2018

and Belgium.

Our focus is on domestic renewable energy production per capita. This differs from the focus on consumption used in the existing literature that follows the EU's preferred measure: 'share of renewable energy in gross final energy consumption'. Our choice of the outcome variable is motivated by three related reasons. First, it is more appropriate for this study's purposes because the logic of our argument is that the production of one type of commodity creates obstacles to the production of another. Second, while we recognize that the costs and benefits of producing renewable energy can vary across countries, we take the production of renewables as a stronger and more direct indicator of a country' commitment to the renewable energy transition. Theoretically a country can continue producing substantial amounts of non-renewable energy for export while consuming more renewable energy at home. A production measure can better indicate whether the country is undertaking or shunning costly reforms and investments required by renewable energy transition. Finally, measuring renewable energy as a share of consumption can also bias results according to the amount of total energy consumed, thus making the renewable energy commitment seem smaller in countries that consume substantial amounts of energy, and bigger in countries that consume less energy. Measuring renewable energy as the primary production and on a per capita basis – here an unbiased denominator – tackles these problems.

In terms of our explanatory factors we focus on time-variant country-level variables that potentially affect renewable energy production. The importance of looking at domestic factors is underscored by the EU's heavy reliance on the motivations of its member states to take steps towards renewable energy deployment (Bürgin, 2015; Collier, 1996).

This paper makes several contributions to the literature. To our knowledge, this is the first systematic empirical investigation of the impact of natural resource wealth and petroleum rents on renewable energy production in the EU. Second, unlike much of the existing research on this topic, we supplement our large-N study with a comparative case study that offers a disciplined qualitative inquiry into the processes which purportedly link renewables to natural resource wealth. Third, we contribute to energy policy debates by reassessing the role of policies, governance, and other previously hypothesized factors once the role of natural resources and other factors is duly accounted for. Such policies concern natural resources as well, because, while such wealth is often a structural variable, in the context of democratic countries the distortions engendered by it are amenable to policy (Mehlum et al., 2006; Robinson et al., 2006). Finally, by encompassing the 1997–2015 period and thus offering the most extensive timeframe possible, given our variables, and addressing the call to extend this frame to include more recent years (Marques et al., 2010), we provide the most up-to-date analysis.

The following section briefly reviews the literature. Next, we offer a theoretical framework that guides our study. Subsequently, we outline our research design. We then present the results of the quantitative and qualitative analyses. We conclude with a summary of findings, a note on limitations, and suggestions for future research.

2. Taking stock: domestic factors in renewable energy deployment

Existing research has advanced five major explanations of the variation in domestic renewable energy production in Europe and elsewhere. First, economic performance is an important factor for the success of renewable energy projects. A primary problem to the production of renewable energy seems to be its direct economic costs, which in turn depend on economic development (Cadoret and Padovano, 2016; Eyraud et al., 2011; Strunz et al., 2015). Renewable energy technologies are capital-intensive and thus need large investment, particularly in the early stages of their development (Eyraud et al., 2011: 4). Such costs are far higher in developing countries compared to the developed world (Labordena et al., 2017). In developing countries, labour is often poorly-trained, and the investment climate is much more insecure, which makes the economy of renewable energy production uncertain (Labordena et al., 2017, 54). Similarly, economic growth is found to lead to an increase in renewable energy production (Cadoret and Padovano, 2016).

Second, government's fiscal policies, such as environmental taxes or feed-in tariffs, alter market forces and can thus determine whether the investment in renewables is worthwhile or not (White et al., 2013; Eyraud et al., 2011). Some scholars have argued that an absence of government financial support is a key obstacle to the production of renewables (Strunz et al., 2015; Pohl et al., 2010).

Third, political ideology can also play a significant role. Cadoret and Padovano (2016) find that left-wing governments in Europe are more likely to increase the share of renewable energy than right-wing governments. They maintain that this is due to left-wing parties being less concerned with the market compared to right-wing parties, and thus less conscious about the economic costs these environmental policies may have on the economy (Cadoret and Padovano (2016), 10).

Fourth, recent literature also increasingly sees the success, or lack thereof, of renewable energy projects as the consequence of the interplay between lobbying by vested interests and electoral considerations of politicians (Cadoret and Padovano, 2016; Kirchgässner and Schneider, 2003; Marques et al., 2010; Strunz et al., 2015). From this standpoint, the quality of government can play a significant role because the effectiveness of its bureaucracy, its degree of independence from political pressures, and its regulatory quality are indicators of the strength to which a government can resist the influences of external interests (Cadoret and Padovano, 2016).

Finally, environmental pressures are obvious factors that need to be taken into account. Specifically, high energy dependence and higher environmental degradation can provide strong incentives for renewable energy deployment (Marques et al., 2010).

3. Hypotheses: what role can natural resource wealth play?

Hartwick (1977) argues that natural resource wealth should have a positive effect on renewable energy production because it increases the capital available for investment. This idea echoes the argument that resource rents can be productively invested towards sustainable development of the producing country (e.g. Thampapillai et al., 2014; Van der Ploeg, 2011). The costs of renewable energy production today still exceed the costs of many fossil fuel technologies, making such investments economically unpopular (Labordena et al., 2017: 53). Switching a country's energy dependency to renewables involves large sunk costs. From this point of view, the above argument has an intuitive appeal: large proceeds from non-renewable natural resources should make it easier to overcome the challenge of sunk costs that are associated with renewable energy transition.

However, while overall natural resource wealth can be conducive to renewable energy transition, specific natural resources, such as petroleum, can be harmful due to their potentially corrosive effect on the economy and governance. Since renewable energy production requires innovation and involves economic diversification, it can be hampered by three common interrelated effects of petroleum wealth: rent-capturing by politicians, rent-seeking by vested interests, and lack of incentives for diversification (Ross, 2012; Bulte et al., 2005; Dunning, 2005). For these reasons, Europe can be seen as experiencing a carbon lock-in, reliant on a fossil fuel intense economy due to long history of fossil dependency (Bridle and Kitson, 2014; Lehmann et al., 2012).

First, when they are developed, fossil fuel industries, particularly the petroleum sector, provide unusually high rents for incumbent governments (Ross, 2012). In addition, they supply critical goods to the economy, provide employment, and can be major actors in infrastructure provision (Harvey and Pilgrim, 2014; Lehmann et al., 2012). Thus, forgoing petroleum rents for uncertain prospects of developing renewable energy production can be economically and politically costly for incumbent political leaders.

Second, renewable energy transition is further complicated by the fact that there are active vested interests in the fossil fuel industry (Cadoret and Padovano, 2016; Marques et al., 2010; Strunz et al., 2015). When it has substantial 'market power', fossil fuel industry plays an important role in environmental policy. With such 'market power' the industry has sizeable financial, organizational, and political resources to use as leverage in protecting its interests through active lobbying (Kirchgässner and Schneider, 2003).

Finally, largely resulting from the previous two factors but also because of its unusually high rents (Ross, 2012), petroleum wealth can act as an economic disincentive for innovation required for the development and production of renewables. Countries that enjoy natural resource wealth on average have strong incentives to avoid economic diversification (Dunning, 2005). While other natural resources, such as non-fuel minerals and timber, can be conducive for diversification, petroleum abundance has been found to provide the strongest barrier (Ahmadov, 2014).

We deduce two hypotheses from the above discussion:

Hypothesis 1. Higher total natural resource rents are likely to be associated with higher levels of renewable energy production in EU countries.

Hypothesis 2. Higher petroleum rents are likely to be associated with lower levels of renewable energy production in EU countries.

4. Research design

To examine our hypotheses, we employ a mixed-methods research design. We start with a multivariate panel data analysis to investigate whether natural resource wealth and petroleum rents have significant effects on renewable energy production in the EU. We follow up with a two-N comparative qualitative case study.

4.1. Method 1. Quantitative analysis

4.1.1. Variables

Our statistical analysis covers 28 EU member states in the post-Amsterdam treaty period between 1997 and 2015. While values for some variables in the analysis are not available for all years, our dataset is comprehensive and offers strongly balanced panel data on key variables (N = 509). Table 1 provides descriptive statistics.

Our dependent variable is *RE Production* measured as the 'primary production of renewable energy per capita in gigajoules'. Our independent variables are *Total Resource Rents* and *Petroleum Rents*. To measure *Total Resource Rents*, we use the World Development Indicators (WDI) 'total natural resource rents as a percent of GDP' variable to construct a per capita measure. Ross (2008) shows that the per capita measure avoids potentially serious biases that can stem from using GDP as a denominator. *Petroleum Rents* is measured using the 'oil and gas rents per capita' variable from Ross and Mahdavi (2015). This is considered the most accurate measure and has the advantage of extensive geographic and temporal coverage (Ahmadov, 2011).[1]

Our baseline model includes control variables that reflect the five alternative major explanations. First, to account for the potential effect of economic development and economic growth, we use *GDP per Capita* and *GDP growth* variables from the World Development Indicators (WDI). Second, government fiscal stance on environmental issues is measured through *Environmental Taxes*. These include all taxes whose base is a physical unit with a demonstrated negative effect on the environment (Eurostat, 2017). Third, government political ideology is measured through binary variables on 'chief executive party orientation' (CEP). Fourth, the *Quality of Government* is the average of the ICRG variables 'Corruption', 'Law and Order' and 'Bureaucracy Quality', with higher values indicating higher quality. Finally, we also control for *CO2 Emissions* and *Energy Dependence*.

We also modify the baseline model with the inclusion of other variables. To check whether specific hypothesized aspects of governance have differential effects, we use the *Corruption* perceptions index from Transparency International and *Government Effectiveness* and *Regulatory Quality* variables from Worldwide Governance Indicators (WGI). As a further check of the effect of government quality, we use a "governance principal component" variable derived through Principal Component Analysis (PCA) that reduces all six measures from Worldwide Governance Indicators (Kaufmann et al., 2011) to a few dimensions.[2] We use component one out of six that accounts for 85% of variance.[3] To further proxy for the government fiscal stance on the environment, we constructed a variable *RES-E policies* that measures the number of policies in a given year that promote renewable energy sources for electricity (Jenner et al., 2013). Finally, we use a series of dichotomous variables from the same source that indicate specific RES-E policy choices, such as tendering schemes (reference category), cost containment caps, feed-in tariffs (FIT), quota schemes, and tax incentives/investment grants.[4]

4.1.2. Estimation and model specification

Our choice of the estimation method and model specification depend on several considerations. First, Breusch and Pagan Lagrangian multiplier test for random effects renders evidence of significant differences across countries, suggesting that an OLS regression is inappropriate. Next, we check whether fixed or random effects model should be used. The Hausman test where the null hypothesis is that the preferred model is random-effects yields a statistically significant result, suggesting that country fixed effects should be used.[5] Country fixed-effects model is also appropriate because we are interested in the effect of explanatory factors that vary in time.[6]

Since the Wald test indicated that there is heteroskedasticity in the data, we estimated all models using robust standard errors. From the

[1] We do not find evidence for a multicollinearity concern between *Total Resource Rents* and *Petroleum Wealth,* since their Variance Inflation Factors (VIF) in the baseline model are 2.4 and 1.6, respectively (reported in Supplementary material for space concerns). We thank Referee 1 for bringing our attention to this. In addition, since in subsequent analysis the standard errors of independent variables' coefficients are of moderate size in relation to the sizes of the coefficients, we conclude that the partial effects are estimated with reasonable precision and it is not difficult to unravel the effects of different predictors (Wooldridge, 2012).

[2] We thank Referee 4 for this useful suggestion.

[3] See Supplementary material, Figure 1 for the screeplot of eigenvalues after Principal Component Analysis.

[4] We thank Referee 4 for this useful suggestion. We also tried to include variables on average government expenditure on these schemes and average wholesale electricity prices, but, apart from Platts proprietary data to which we do not have access, other data are incomplete and inconsistent for the period under analysis in this paper. For example, Eurostat data does not cover most of the countries as its pre-2007 data is available only for 11 EU members and is inconsistent over time as it has a break in measurement in 2007, and other data that are scattered across various EU reports (e.g., European Commission market analysis reports) is reported in different formats and inconsistently for different countries. In addition, while in principle it could also be useful to further distinguish between fixed FIT and feed-in premiums, in the period under analysis in our dataset only Denmark had the latter, thus entailing too small a subsample.

[5] The results from random-effects model are not substantively different from the results obtained from fixed-effects.

[6] Technically, time-fixed effects may be useful but from a substantive point of view their inclusion is doubtful because, given a strong general time trend in the push for renewable energy transition, this inclusion absorbs the effects of time-varying variables that are of much higher interest for comparative research.

Table 1
Descriptive statistics.

Variables	Measurement	N	Mean	SD	Min	Max	Source
Dependent							
RE Production	Per capita primary production of renewable energies in gigajoules, logged	509	2.46	1	0	4.84	Constructed from Eurostat (2017) (energy) and World Bank (2017) (population)
Independent							
Total Resource Rents	Per capita total natural resource rents in constant 2011 USD, logged	509	8.91	1.81	3.22	13.54	Constructed from World Bank (2017)
Petroleum Rents	Per capita oil and gas rents in constant 2014 USD, logged	509	2.78	2.63	0	10.25	Ross and Mahdavy (2015)
Control							
GDP per Capita	GDP per capita, PPP, in constant 2011 USD, logged	509	10.3	0.45	9.05	11.49	World Bank (2017)
GDP Growth	GDP growth, annual %	509	2.4	3.52	− 14.81	11.89	World Bank (2017)
Environmental Taxes	Per capita environmental tax revenues in constant 2015 euro, logged	509	6.08	0.9	2.69	7.62	Constructed from Eurostat (2017) (taxes) and World Bank (2017) (population)
Ideology: Center	1 = Chief executive party orientation is center	509	0.13	0.33	0	1	Beck et al. (2001)
Ideology: Left	1 = Chief executive party orientation is left	509	0.35	0.48	0	1	Beck et al. (2001)
Quality of Government	ICRG indicator of quality of government	509	0.76	0.16	0.39	1	PRS (2016)
CO2 Emissions	CO2 emissions in metric tons per capita	509	8.10	3.46	2.68	24.82	World Bank (2017)
Energy Dependence	Net imports/sum of gross inland energy consumption plus bunkers	491	54.0	29.28	− 49.80	109.50	Eurostat (2017)
Corruption	Corruption perceptions index	494	64.2	19.32	26	100	Transparency International (2016)
Government Effectiveness	Government effectiveness index	429	1.19	0.64	− 0.62	2.36	Kaufmann et al. (2011)
Regulatory Quality	Regulatory quality index	429	1.21	0.43	− 0.12	2.08	Kaufmann et al. (2011)
Governance PC	Principal component 1 from Principal Component Analysis (PCA) of six WGI measures	429	0.05	2.23	− 5.74	3.86	Constructed based on Kaufmann et al. (2011)
RES-E Policies	Number of policies enacted for promoting renewable energy sources for electricity	478	1.86	1.15	0	4	Constructed based on Jenner et al. (2013) data

Notes: Some variables are log-transformed to avoid skew (Cameron and Trivedi, 2010). 'Ideology: Right' is a reference category for ideology.

Wooldridge test we concluded that there is autocorrelation in the data. Since our dataset is not a macro panel (> 20–30 years) and has smaller T relative to N, autocorrelation is a minor issue (Wooldridge, 2010). However, since it can yield smaller standard errors and larger R-squared values than warranted, we address it by clustering the robust standard errors by country. To reflect the appropriate time delay in the potential effect of independent variables on the dependent variable, we follow the literature and use 2-year time lags for rent variables, economic development, growth, and environmental taxes, and 3-year lags for the variables that reflect government ideology, quality of government, CO2 emissions, and energy dependence (we vary these lags in robustness checks).[7] Thus, the baseline equation is:

$$\begin{aligned} RE\ \ Production_{it} = {} & \beta_1 Total\ \ Resource\ \ Rents_{it-2} + \beta_2 Petroleum\ \ Rents_{it-2} \\ & + \beta_3 GDP\ \ per\ \ Capita_{it-2} + \beta_4 GDP\ \ Growth_{it-2} \\ & + \beta_5 Environmental\ \ Taxes_{it-2} + \beta_6 Ideology_{it-3} \\ & + \beta_7 Quality\ \ of\ \ Government_{it-3} \\ & + \beta_8 CO2\ \ Emissions_{it-3} + \beta_9 Energy\ \ Dependence_{it-3} \\ & + \alpha_i + \upsilon_{it} \end{aligned}$$

4.2. Method 2. A qualitative case study

In the small-N study, we focus on the cases of two countries that have many similarities but differ in the amount of natural resource wealth. The objective here is to unravel the potential impact of natural resource wealth, or lack thereof, on these country's political economy and incentives for diversification, and how these may have affected renewable energy production in each case. Here we draw on evidence from the analysis of policy documents, mass media, and secondary sources.

Such small-N comparative qualitative analysis complements the large-N econometric analysis by enabling an in-depth exploration of the underlying mechanisms in the relationship between natural resource wealth and renewable energy production. By illustrating, through the use of detailed historical evidence, the workings of actors and processes that link our variables of interest, the case study puts the findings of the regression analysis in political-economic and policy context of specific countries and thus provides additional explanatory leverage. Finally, by offering more fine-grained evidence on key variables, it allows to fill potential gaps that may be left by the econometric analysis' inevitable reliance on cross-country measures that enable parsimony and strengthen external validity but may not capture all dimensions of important factors.[8]

We focus on the cases of the Netherlands and Belgium in the period before and after their ratification of 2020 Energy Strategy in 2009. The two countries share many political, economic, cultural, and geographic similarities. They have similar political systems (parliamentary system and constitutional monarchy), similar levels of economic development, standards of living, population sizes, geographic area, and are both relatively flat and densely populated (IEA, 2016). Yet, they differ considerably in natural resource wealth. The Netherlands has been classified as a top 10 natural gas-producer since it discovered natural gas fields in the 1960s (Aardgas in Nederland, 2017). These discoveries have meant large petroleum rents. Belgium, on the other hand, is resource poor and has no petroleum wealth. Although once coal was the main indigenous source of energy, since early 1990s the supplies have been mostly exhausted or economically unattractive to extract, and the domestic production stopped after the closure of the last mine in 1992 (IEA, 2016). Another difference between the two countries is the fact that Belgium is a federal state and therefore historically divided between the Dutch speaking part, the Flemish region, and the French speaking part, the Walloon region. This factor, however, should be a disadvantage to Belgium as it may lead to an inconsistent policy with

[7] Substantively, given the structural nature of our key independent variables (Ross, 2012; Bulte et al., 2005; Dunning, 2005), we do not see concerns for reverse causality between our variables of interest and thus little value in complementing the fixed-effects panel data analysis with instrumental-variables techniques.

[8] We are grateful to Referee 1 for suggesting to highlight the value added by the case study.

Table 2
Predictors of renewable energy production in the EU, 1997–2015.

	Dependent variable: RE Production							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total Resource Rents$_{t-2}$	0.094***	0.099***	0.065**	0.088***	0.062**	0.066**	0.086***	0.095**
	(0.031)	(0.027)	(0.027)	(0.026)	(0.025)	(0.035)	(0.030)	(0.039)
Petroleum Rents$_{t-2}$	− 0.113***	− 0.099***	− 0.093***	− 0.102***	− 0.099***	− 0.078**	− 0.096**	− 0.123***
	(0.037)	(0.032)	(0.029)	(0.030)	(0.033)	(0.034)	(0.044)	(0.041)
GDP per Capita$_{t-2}$	0.640**	0.607***	0.841***	0.696***	0.946***	0.530**	0.736**	0.486
	(0.258)	(0.194)	(0.265)	(0.223)	(0.255)	(0.234)	(0.336)	(0.428)
GDP Growth$_{t-2}$	− 0.011***	− 0.011***	− 0.007***	− 0.009***	− 0.008***	− 0.007**	− 0.009***	− 0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Environmental Taxes$_{t-2}$	0.334***	0.370***	0.338***	0.368***	0.295***	0.295***	0.491***	0.335**
	(0.093)	(0.091)	(0.101)	(0.086)	(0.091)	(0.092)	(0.098)	(0.153)
Ideology: Center$_{t-3}$	− 0.122**	− 0.132**	− 0.078	− 0.111*	− 0.081*	− 0.113**	− 0.138**	− 0.007
	(0.052)	(0.060)	(0.052)	(0.055)	(0.042)	(0.047)	(0.050)	(0.039)
Ideology: Left$_{t-3}$	− 0.014	− 0.013	− 0.022	− 0.024	− 0.018	− 0.027	− 0.012	− 0.025
	(0.033)	(0.035)	(0.031)	(0.029)	(0.026)	(0.035)	(0.038)	(0.021)
Quality of Government$_{t-3}$	− 0.391					− 0.370	− 0.179	0.492
	(0.559)					(0.588)	(0.617)	(0.879)
CO2 Emissions$_{t-3}$	− 0.082	− 0.083	− 0.075**	− 0.081*	− 0.071*	− 0.071	− 0.087*	− 0.093***
	(0.050)	(0.051)	(0.034)	(0.042)	(0.036)	(0.048)	(0.051)	(0.019)
Energy Dependence$_{t-3}$	0.003	0.004	0.001	0.003	0.001	0.003	0.003	− 0.002
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Corruption$_{t-3}$		− 0.002						
		(0.006)						
Government Effectiveness$_{t-3}$			− 0.393***					
			(0.132)					
Regulatory Quality$_{t-3}$				− 0.146				
				(0.120)				
Governance PC$_{t-3}$					− 0.162***			
					(0.041)			
Number of RES-E Policies$_{t-3}$						− 0.179***		
						(0.048)		
Cost Containment Cap$_{t-3}$						0.365***		
						(0.069)		
Feed-In Tariff$_{t-3}$						0.402***		
						(0.116)		
Quota Scheme$_{t-3}$						0.318**		
						(0.149)		
Tax incentive/grant$_{t-3}$						0.177**		
						(0.085)		
Constant	− 5.821**	− 5.945***	− 7.477***	− 6.658***	− 8.772***	− 4.475**	− 7.939**	− 4.456
	(2.330)	(1.500)	(1.974)	(1.675)	(1.954)	(2.001)	(3.283)	(3.917)
Observations	436	423	362	362	362	424	381	196
Countries	28	28	28	28	28	27	28	28
'Within R-squared'	0.621	0.615	0.645	0.599	0.650	0.657	0.590	0.401
F	18.50***	19.07***	28.73***	23.49***	35.30***	25.42***	21.50***	10.05***

Note: All models use country fixed effects, employing within-regression estimator. In parentheses are robust standard errors clustered by country. 'Ideology: right' is a reference category for ideological binaries. Model 6 excludes Croatia since data on RES-E policies is not available for it. Model 6 uses "Tendering Scheme" (Jenner et al., 2013) as a reference category for RES-E policies. Model 7 restricts observations to years since a country became official member of the EU. Model 8 restricts observations to the period after the adoption of the 2020 Energy Strategy.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

regards to renewables throughout the country.

5. Quantitative analysis results and discussion

To summarize, the results in Table 2 confirm the expectations of this paper. In line with our hypotheses, while natural resource rents are associated with an increase in renewable energy production, petroleum rents are consistently associated with a decrease. Both relationships are statistically significant at least at 0.05 level, controlling for other factors suggested in the literature.

To interpret the results in Model 1 in terms of partial elasticities: if total natural resource rents per capita increase by 10%, we would expect renewable energy production in gigajoules per capita to increase by about 0.9%, holding other independent variables constant. Conversely, if petroleum rents per capita increase by 10%, we would expect the production of renewable energy gigajoules per capita to decrease by 1.1%, holding all other predictors constant.

These results remain largely the same when we modify the baseline model to use different aspects of governance (Models 2–4) or a "governance principal component" (Model 5), include RES-E policies (Model 6), restrict observations to years since a country became an official member of the EU[9] (Model 7) and to the period after the adoption of the 2020 Energy Strategy to see whether the latter has affected the relationships of interest (Model 8). All models provide a good fit. The values of pseudo-R squares (within) for Models 1–7 suggest that the models account for about 60% and for Model 8 for about 40% of the variance within the panel units.

[9] The rationale for including years when the country had not yet become an EU member is that it was likely to be pushed to move towards renewable energy in the pre-accession period (Knill and Tosun, 2009).

Our main results regarding the effects of natural resource rents survive multiple robustness checks (Supplementary material, Table 3), such as accounting for potential effect of R&D expenditure per capita; regionalist producer interests that can hinder environmental programmes (Kirchgässner and Schneider, 2003); dropping energy dependence and environmental taxes variables, and increased or shortened time lags.

Three other patterns arise from our models. First, somewhat surprisingly, the results indicate that, while an overall higher level of economic development is indeed conducive for renewable energy production, higher growth may hamper it, possibly because it advantages existing sources of energy by requiring a larger supply of energy than can be currently delivered by renewable energy projects.

Second, policy variables seem to matter consistently more than governance variable and temporal changes in environmental pressures. While ideology makes a difference in that centrist chief executive parties (CEPs) may be less conducive to renewable energy production than right CEPs, having a left-oriented CEP does not have a statistically significant different effect on renewable energy production than having a right CEP. Once other factors are taken into account, surprisingly, the quality of government does not seem to exert a consistent, positive, statistically significant effect as expected based on previous knowledge, and in two models governance quality and government effectiveness have negative signs. While this might be suggesting a lack of true effect, it may also indicate that prominent cross-national measures of government quality are rather general to sense energy-specific areas where governance quality may indeed matter for renewable energy production. Furthermore, contrary to some arguments, temporal changes in environmental pressures, such as CO2 emissions and energy dependence, do not have a consistent, statistically significant effect when other factors are accounted for. On the other hand, there is strong evidence to support the hypothesis on the importance of actual fiscal policy commitment and of policy choices on renewables. Contrary to some previous findings, environmental taxes have a consistent, positive, statistically and substantively significant effect on renewable energy production.

Finally, policy design choices on renewables matter, confirming some previous findings (Jenner et al., 2013), but merely increasing the number of policies may prove detrimental. Compared to tendering schemes, feed-in tariffs seem to have highest impact on renewable energy production, followed by cost-containment caps, quota schemes, and tax incentives/investment grants. Investing in R&D may also boost renewable energy production (Supplementary material, Table 4).

6. A case study: renewable energy transition in the Netherlands and Belgium

Before 2009, when both the Netherlands and Belgium ratified the 2020 Energy Strategy, they had different levels of renewable energy production (Fig. 1, Panel A). While Belgium initially lagged behind, by 2009 it caught up with the Netherlands. In terms of the share of renewable energy in gross final energy consumption (Fig. 1, Panel B), the two countries entered the 2020 Energy Strategy with similar levels. The differences in initial capacities corresponded to different 2020 targets: the Netherlands had to reach a share of 14% of renewable energy in final consumption by 2020, this was 13% for Belgium. The Dutch target was seen as very modest compared to others, partly because of the country resource endowments (Oteman et al., 2014).

Due to the similar geographic properties, both countries have pursued similar options for renewable energies. In the Netherlands, the renewable energy mix in 2009 consisted largely of biofuels and waste, followed by wind energy (IEA, 2014: 106). Over time, this mix has not diversified. While energy from biofuels and wind has grown marginally, other alternative forms of renewable energy, such as geothermal energy, have actually decreased in use (*ibid.*). Similarly, Belgium also entered the 2020 Energy Strategy with a renewable energy mix that was predominantly characterized by biofuels and waste (IEA, 2016: 117). Yet, over time, renewable energy production has diversified as the amount of solar energy increased (IEA, 2016).

The two countries have made different progress towards achieving their goals. In terms of renewable energy production, over the course of five years the Netherlands increased its productive capacity per capita by 3.98 GJ, while Belgium improved its capacity by 4.23 GJ. Thus, Belgium increased its capacity by 0.25 GJ per capita more than the Netherlands. This difference may seem small because it is expressed in per capita units but it is sizeable cross-nationally. In 2015, 65% of Belgium's total energy production came from nuclear energy, but its renewable energy accounted for 28.5% of the total production (Table 3). In the same year, petroleum accounted for 86.3% of the Netherlands' energy production, while its renewable energy was around 10%.

If we use the consumption-based measure used by the EU, the contrasting progress of the Netherlands and Belgium towards their renewable energy goals is even starker (Fig. 1). While the Netherlands increased its renewable energy share in final energy consumption by 1.26% over the five-year period, Belgium increased its share by 3.80%. This meant that in 2014, Belgium was 3.96% away from meeting their 2020 obligation, while the Netherlands needs to increase its share by 8.33% if it wants to reach its target.

Thus, despite their similarities, the Netherlands and Belgium exhibit noticeable variation in terms of renewable energy deployment both in terms of production and consumption. Below we explore how varying levels of natural resource wealth can help explain these differences.

6.1. Rent-capturing? Natural resource rents and government revenues

The Netherlands relies significantly on the natural resource sector as a source of income for its national budget. Between 2009 and 2014,

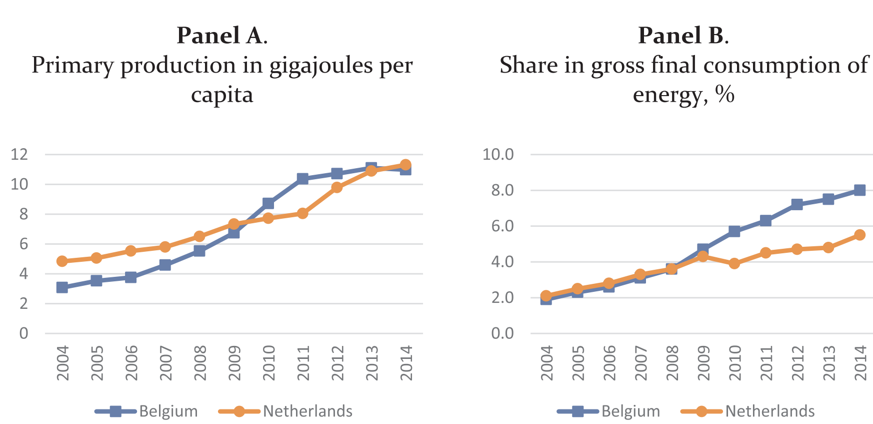

Fig. 1. Renewable energy in the Netherlands and Belgium.

Table 3
Energy production in the Netherlands and Belgium, 2015.
Source: Eurostat (2017).

	Share of total production, 2015 (%)				
	Nuclear energy	Solid fuels	Natural gas	Crude oil	Renewable energy
Belgium	65.0	0.0	0.0	0.0	28.5
Netherlands	2.2	0.0	82.0	4.3	10.1

revenues from the natural gas production comprised on average between 5% and 10% of total government revenues (Aardgas in Nederland, 2017). More than 50% of the revenues generated from natural gas comes from sources other than tax revenue (Aardgas in Nederland, 2017). This is due to the fact that the Dutch government set up the EBN, a public company, which acts on behalf of the government in investing, exploring, and extracting natural gas in the Netherlands since 1973 (EBN, 2017).

Belgium, on the other hand, does not have such a source of government revenue. Yet, government revenue, measured in percentages of GDP, was actually higher in Belgium throughout the period under investigation compared to the Netherlands. While on average the Belgian government revenue comprised around 50% of the country's GDP, the Dutch government revenue comprised around 43% (OECD, 2017). Belgium earned this revenue mainly through taxation. Unsurprisingly, Belgium has one of the highest tax rates in the European Union, particularly in terms of taxes on electricity, while these are comparably low in the Netherlands (Deloitte, 2013).

A large share of government revenue comprised of natural resource rents is, of course, by itself not necessarily problematic. The resource curse literature emphasizes that resource wealth become a ‘curse’ only if pre-existing institutions are characterized by a lack of accountability, and can be a blessing in a democratic system with strong checks and balances (Mehlum et al., 2006). Precisely because the Netherlands is considered a country with strong democratic institutions, natural resource revenues should provide it with a comparative advantage over Belgium in terms of the renewable energy sector development, as it has more capital to develop it. Yet, that would entail that resource revenues would proceed to the development of these sectors (Riley, 1980).

However, available evidence points at some manifestations of economic mismanagement of natural resources in the Netherlands. Early problems with abundant resource rents and an over-reliance on these rents for the development of the public sector led the country to suffer from the ‘Dutch Disease’ after the discovery of large gas reserves in the 1950's, as government spending became unsustainable and crowded out traditional economic sectors (Banning, 2009). This problem was overcome, but some negative effects of resource wealth appear to have continued. First, how the successive governments have spent resource rents is not transparent and sometimes untraceable (Algemene Rekenkamer, 2014). Second, income from natural resources has frequently financed consumption, including the Dutch welfare state, rather than invested, indicating a widespread problem in natural resource-rich countries when proceeds from resource wealth extraction are treated as income rather than assets (Banning, 2009; Humphreys et al., 2007; Jackson and Evrengün, 2006).

These trends continued despite the establishment in 1995 of the ‘Fund for Strengthening Economic Structures’ (FES), to which some part of the gas revenues was allocated (Hers and Suyker, 2014). The primary goal of this fund was to invest revenues in infrastructure as well as for research into the environment (Jackson and Evrengün, 2006). However, in 2005 the fund's mandate was expanded to include spending on the development of the knowledge economy in what came to be called as investment into ‘environment, education, innovation’ (Hers and Suyker, 2014). This reformulation considerably expanded the room for interpretation, allowing policymakers to channel funds to finance sizeable projects of dubious worth. For instance, in 2006, only 14 projects out of 49 were evaluated to be beneficial to Dutch welfare; in 2008, out of 23 projects, only 6 were considered worthwhile (Banning, 2009; CBP, 2008). The changing of the rules of the FES to an alternative that suits the needs of incumbent political leaders is a recognized pitfall of natural resource funds across the world (Humphreys and Sandbu, 2007).

Not having such a fund that could have been tapped into as a source of income, Belgium has avoided some of the problems experienced by the Netherlands. Since Belgium lacks its own resources, it has become dependent on imported energy (Deloitte, 2013: 2). This has, on several occasions, threatened the country's energy security, which led to the establishment of a public stockholding company (APERTA) to manage oil shocks (Deloitte, 2013). Belgium has been also heavily reliant on nuclear energy, which produced 55% of Belgium's electricity in 2013 (Deloitte, 2013). However, the public backlash that has been spreading regarding nuclear energy has increasingly challenged Belgium's energy security even further, as it is planning to ‘phase-out’ nuclear energy between 2015 and 2025 (Deloitte, 2013).

6.2. *Rent-seeking? Influence of vested interests*

In addition, in the Netherlands fossil-fuel corporations have had strong influence on government policy, particularly those involved in the petroleum sector. Royal Dutch Shell, Gasunie (Dutch natural gas infrastructure and transportation company), and Exxon have strong lobbies (Oteman et al., 2014; Ulmanen et al., 2009). The petroleum sector also has indirect lobbying influence because agriculture and transport sectors are heavily subsidized for using fossil fuels and, therefore, have also been engaged in lobbying for fossil fuels (Oteman et al., 2014). This influence has resulted in the creation and sustenance of more than 50 government interventions that favour the usage of fossil fuels among businesses and households (Oteman et al., 2014). In comparison to the influence of these vested interests, the political influence of the lobby for renewable energy has been very limited as it lacks similar economic leverage. For example, unlike Germany with its large industry for solar panels and Denmark with its turbine manufacturing, the Netherlands does not have a sizeable industry for building renewable facilities (Oteman et al., 2014).

Despite relying on gas imports primarily from the Netherlands and Norway and having an oil refinery sector (Chellingsworth et al., 2016), the near-absence of domestic production has limited the influence of fossil fuel producers in Belgium compared to the Netherlands. Competences on energy matters are divided between the federal state and the three regions, resulting in four energy regulators (Chellingsworth et al., 2016). While this has complicated decision-making on energy policy, it has also allowed multiple entry points for smaller and varied interest groups. While the neo-corporatist system in Belgium has traditionally led to centralized access and limited the number of mobilized interest groups, some features of its political system such as multi-layeredness allow the entrance of various interest groups (Fraussen and Beyers, 2016). Such system also allows interest groups to target several levels (Destrooper, 2017).

6.3. *(Limited) diversification towards renewable energy*

In general, evidence points at a lack of commitment towards the renewable energy sector in the Netherlands compared to Belgium, although this has varied over time. For example, while some coalitions in the Dutch government were keen on pursuing renewable energy options, others have been less inclined. The 2005 government under the mandate of the CDA (Christian Democratic Alliance), Labour and the Christian Union set a national target of 20% of renewable energy for 2020, the elected government in 2009, with the VVD (People's Party for Freedom and Democracy) and CDA in power, abandoned this target (Statistics Netherlands, 2010).

Furthermore, while the Netherlands used to have a subsidy scheme (the MEP schemes) for the production of renewable energy, which helped the country in achieving 9% electricity production from renewables by 2009 by providing large amounts of fiscal incentives, this scheme was abandoned in 2006 even though it was a success (Statistics Netherlands, 2010: 20). Although the Dutch government reasoned that this prevented a huge budget overspill as the target for which the subsidy scheme had been set was achieved, the new subsidy scheme (the SDE), which put a limit to the subsidy available, was only introduced in 2008, leaving a two-year gap of uncertainty (*ibid.*).

In 2011, this new subsidy scheme was promptly replaced by the SDE + (Stimulering Duurzame Energieproductie), which left the production of renewable energy more over to the market by providing fiscal support through a feed-in support scheme (OECD, 2014: 111). While this scheme is supposed to equalize the price of renewables to fossil fuels, recent reports have shown that the subsidy scheme has had little effect on the production of renewables as it is simply too low (Algemene Rekenkamer, 2015).

These different decisions have had serious consequences for the renewable energy sector. Namely, the many changes to the subsidy schemes have increased uncertainty of investors as they have had little reassurance about ‘financial preconditions’ (Statistics Netherlands, 2010: 23). The problem the Netherlands is facing is clearly that a long-term policy would mean strong commitment to renewable energy production. In the face of sufficient non-renewable resources, politicians in the Netherlands are fairly unwilling to make this commitment (Statistics Netherlands, 2010, 28).

Belgium on the other hand, has not had similar difficulties in renewable energy policies. Unlike the Netherlands, the Belgian government has shown stronger commitment to creating incentives for investments through subsidies (IEA, 2016). For example, in 2013, support costs for renewable electricity ‘ranged from EUR 24.11 per MWh for hydropower to EUR 369.07 per MWh for solar PV’ (IEA, 2016, p. 123). This meant that the Belgian government provided the fourth-highest level of support to renewables in Europe, after the Czech Republic, Italy, and Greece (IEA, 2016, p. 123).

While Belgium, like the Netherlands, is also suffering from a lack of confidence from renewable energy investors, this is due to a different reason: while the Dutch problem comes from a lack of consistent governmental support, the Belgian problem is due to too much government support. This has led to excess demand and a struggle of the Belgian authorities to get the support scheme just right (IEA, 2016: 126). Consequently, unlike the Netherlands, another problem Belgium faces is not that its politicians are not willing to invest in renewables, but rather, that they are willing to invest too much.

7. Conclusion and policy implications

This paper offers the first systematic empirical investigation of the effect of natural resource wealth on renewable energy production across the EU since 1997. Its theoretical framework reconciles divergent views on the role of natural resources. Using a mixed-methods research design that combined panel data analysis with an in-depth comparative case study, the paper shows that while overall natural resource abundance may be conducive, petroleum wealth negatively affects renewable energy production in the EU. Through employing new and better measures and a small-N study that allows exploring processes at closer range, this contribution arrives at findings that confirm suspicions of several previous studies (e.g., Marques et al., 2010). These findings echo the resource curse literature (Ross, 2012; Bulte et al., 2005; Dunning, 2005) and suggest that, even in the presence of strong democratic institutions, countries with petroleum wealth can find it difficult to avoid potential pitfalls of this wealth. However, in democratic institutional environments characterized with strong accountability, the distortions triggered by such wealth are amenable to policy interventions (Mehlum et al., 2006; Robinson et al., 2006). Our findings show the continuing relevance of the argument that to achieve the ambitious goals on renewable energy deployment, the EU indeed needs additional and stricter policies (Harmelink et al., 2006).

These findings contribute to the debates on European energy policy by suggesting a number of implications for the EU and national policies. First, the EU and member states can generally harness rents from natural resource wealth to provide a required capital to address the challenge of sunk costs for renewable energy production, such as through financing facilities for renewables. Yet they should also undertake stronger fiscal and regulatory interventions to explicitly tackle continued pernicious effects of specific natural resources, such as petroleum, including rent-capturing by politicians, rent-seeking by vested interests, and lack of incentives to diversify. Given our findings, one potential measure is developing a strict roadmap for phasing out fossil-fuel subsidies in production and consumption, such as curtailing investment in fossil fuel infrastructure, preferential tax treatment, or royalty exemptions. On national level, these can be envisaged through, for example, national budgets' direct payment systems, fiscal (dis)incentives, and national development banks. On the EU level, this can be contemplated through, for example, the EU budget and European Fund for Strategic Investments (EFSI).

Other measures can include tightening the EU Emissions Trading Scheme to reduce manipulation and loophole exploitation by vested interests (Strunz et al., 2015) and lending stronger and higher-level support to renewable energy advocacy coalitions so as to reduce the unevenness of the political playing field (Lehmann et al., 2012). In combination with bolstering R&D spending, such support can also facilitate learning and knowledge spill-overs (Lehmann et al., 2012). As our case study suggests, the timing of policies is important, and pro-renewable energy groups should capitalize on the momentum presented by such events as increasingly serious earthquakes in Groningen in the Netherlands that are due to its continued production of gas.

Second, our findings suggest that actual fiscal policy commitment, such as levying higher environmental taxes and policy design (e.g., the choice between feed-in tariffs, quota schemes, and tendering), have substantially higher impact for supporting renewable energy production than government ideology, quality of governance or temporal changes in environmental pressures. Furthermore, increasing the number of policies to support renewable energy projects without attention to policy design may actually be counterproductive. Finally, for the intended positive effect to occur, policies affecting renewable energy production directly or indirectly should be made not only transparent, but also consistent and stable. The case of the Netherlands suggests how such inconsistency and instability can be linked to petroleum revenues. Thus, we re-iterate with new evidence the importance of reducing such inconsistency (White et al., 2013). Given increasing cross-national policy learning and spill-overs related to petroleum production, it is imperative to embed national RES policies in an integrated EU-wide system with comprehensive energy scenarios and partially harmonized rules (Lehmann et al., 2012).

Naturally, our study has limitations. First, while the measures of natural resource wealth are the best currently available, for the purposes of our analysis ideally they would be supplemented by measures of the state's fiscal reliance on such resources. The problem, however, is that such measures currently do not exist, although progress is being made.[10] Second, while our research design aims to minimize omitted variable concerns by adopting purportedly exogenous factors, by controlling for confounders advanced in the literature, and by exploring causal processes through an in-depth comparative qualitative study, such concerns cannot be ruled out. Finally, we aimed at rigour in the small-N study by selecting cases that are very similar, but the fact remains that no two countries can ever be the same and that the results

[10] The work of Haber and Menaldo (2011) and ICTD/UNU-WIDER (2016) is thus promising.

from such analysis may not travel far beyond the original cases.

From this study, there are also two particularly important ways to go forward for further research. First, the mechanisms explaining the relationships between resource wealth and renewable energy production should be further investigated. This study's inclusion of qualitative analysis acted as an additional insight into the relationship observed by quantitative analysis. However, future research should focus on comparing more cases, and perhaps focusing more on micro-level decision-making, carefully investigating the choices made by relevant actors and the effect of these choices on policy making. Second, work should be done towards the development of accurate measures that capture a state's fiscal reliance on the non-renewable energy sector.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2018.11.044.

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