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Institutions and Geography: A “Two Sides of the Same Coin” Story of Primary Energy Use in Sub-Saharan Africa

Laté Ayao Lawson^a and Phu Nguyen-Van^b

ABSTRACT

Do institutional and geographical characteristics matter for energy consumption similar to the case of economic development? Why do coastal Sub-Saharan African (SSA) countries appear to be more energy-consuming than inland ones? To answer these questions, surprisingly rarely addressed in the existing literature, we empirically assess the determinants of primary energy use across SSA, exploiting spatial analysis methods. Our results highlight the existence of positive geographical spillovers in primary energy use. We also derive factors (income, exports, population dynamics and urbanization) explaining the reasons coastal countries are more energy-intensive. Furthermore, good political institutions and geographical location enhance primary energy use, connoting a “two sides of the same coin” role played by both factors. Our results impel SSA countries to develop alternative energy strategies and deploy energy resources management policies since adverse environmental consequences associated with increasing fossil energies use are to expect in the near future.

Keywords: Primary energies, Geography, Institutions, Spatial effects, Development

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1. INTRODUCTION

The acceleration of ecosystem depletion and gas emissions has motivated systematic studies on the socio-economic drivers of natural resources and fossil energy use. This is the case in recent studies by Medlock and Soligo (2001), Wolde-Rufael (2009), Van Benthem and Romani (2009), Özokcu and Özdemir (2017) and Antonakakis et al. (2017), among others, on the energy use and economic development nexus. The present paper offers a new perspective into primary energy use characteristics of SSA countries by investigating an issue which has surprisingly received less attention from the literature so far: The role of political institutions and geographical characteristics in primary energy use.

Existing works on energy use predominantly focus on the income-energy link, analysing causality, long-run dynamics and the so-called Environmental Kuznets Curve hypothesis for energy use. Further aspects question the drivers of energy demand and the channels through which energy availability enhances economic development. In this scholarship, relatively rare mentions of the role of institutional and geographical characteristics of countries (location, weather differentials and spatial spillovers) can be identified. Aiming to fill that gap, our paper analyses how institutions and ge-

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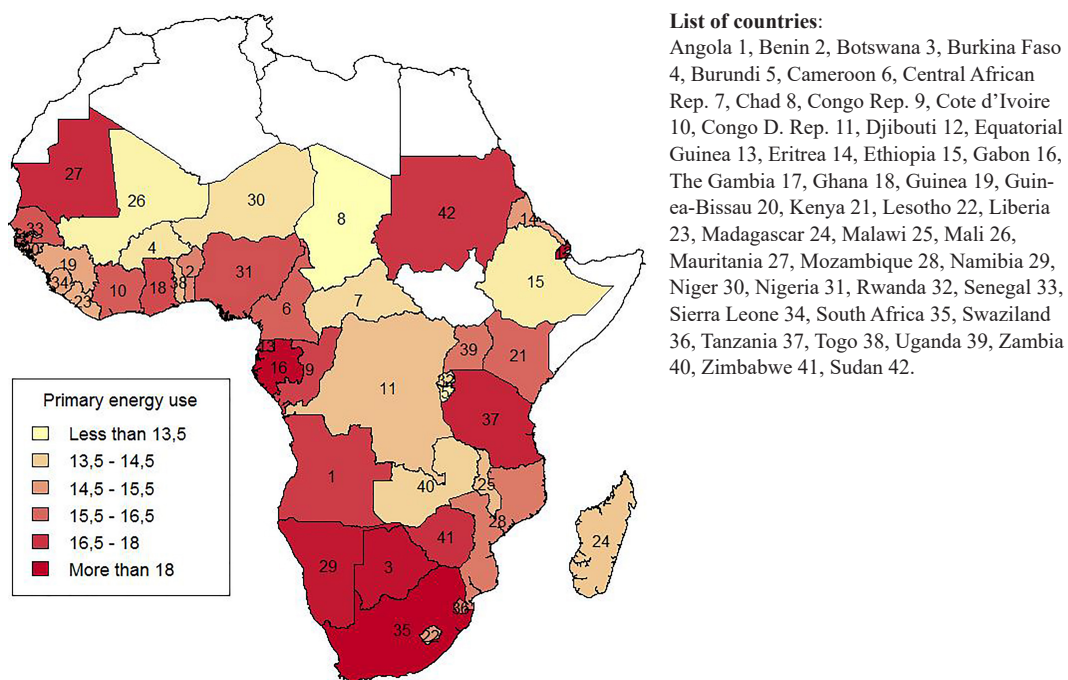
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ography influence energy consumption in SSA, accounting for usual socio-economic characteristics such as income and urbanization level and population dynamics, among others. Thereby, we argue that neighbouring SSA countries sharing similar geographical characteristics also show comparable profiles of energy use. This relation is also enhanced by institutional quality.

SSA countries being pre-industrial and highly resources-dependant economies, investigating topics relative to endowments in energy resources and primary energy use as well as related environmental consequences seems pertinent. Moreover, the “Geography versus Institutions” debate mainly animated by Acemoglu et al. (2001, 2005, 2008), who stressed the role of institutions, against Sachs (2003), Gallup et al. (1999); Sachs et al. (2001) and Diamond (1999), who supported the predominance of geographical characteristics, points out the importance of both factors in economic development. Hence, institutions and geography being among factors explaining economic growth, they likely play a similar role in energy consumption. In this perspective, introducing geographical factors and political institutions in a study of the determinants of primary energy use in SSA appears promising.

The contribution of our spatial analysis of primary energy use is twofold. Firstly, observing Figure 1, we can claim that location matters to endowments in fossil energies as well as in primary energy use, since high energy use is mostly observed in coastal located countries. Additionally, looking from the South to the North, it appears that countries with lower energy use such as Chad, the Democratic Republic of Congo, Mali, and Ethiopia are mostly surrounded by countries with higher levels of energy consumption. As coastal and geographically contiguous SSA countries show comparable energy consumption levels, there might be some geographical spillovers in primary energy use and this analysis intends to consider that. Secondly, since SSA countries are being classified among the fastest growing economies, institutional and geographical factors seemingly play a significant role in their economic performances and therefore in energy use. Thus, our analysis

Figure 1: Mean primary energy use per capita observed between 1990–2013, in thousands of Kj.



proposes to account for institutions and geography, arguing that both factors also affect primary energy consumption, acting as the “two sides of the same coin”.

The outline of the paper is as follows. Sections 2 and 3 present the related literature and the data. Section 4 comprehensively describes our econometric approach. Section 5 presents and discusses the estimation results. In Section 6, we provide some robustness check. Section 7 concludes the paper.

2. RELATED LITERATURE

The empirical literature on energy demand and economic development seems large in terms of contribution and methodological approach. Our paper broadly addressing the determinants of energy use, this literature review focuses on causality and long-run dynamics analyses, the energy-income nexus as well as the socio-economic drivers of energy use.

Being input in production activities, energy use reversely depends on income level. In addition to investigating the direction of causality, a first group of authors contributes by estimating the long-run relationship between energy and income. This is the case in Glasure and Lee (1998), Asafu-Adjaye (2000), Soytaş and Sari (2003), Altınay and Karagöl (2004), Lee (2005, 2006), Huang et al. (2008), Joyeux and Ripple (2011), Tang and Tan (2012) and Omri (2014), among others. Reviewing this literature, a lack of unanimity regarding the direction of the causality is noticeable (Oztürk, 2010), motivating systematic meta-analyses (Menegaki, 2014; Bruns et al., 2014; Sebri, 2015), which lead to even ambiguous conclusions.

In the SSA context, the empirical results do not contrast with the previous ones. At country level, the results by Odhiambo (2009a) point to a stable long-run relationship with a unilateral causality running from energy to GDP in Tanzania, while in South Africa there seems to be a bidirectional causality (Odhiambo, 2009b). The conclusions by Ebohon (1996), Wolde-Rufael (2009) and Esso (2010) partly support this bidirectional causality. Akinlo (2008) provides country-level analyses to find a bidirectional causality in Gambia, Ghana and Senegal, while no causality is observed in Cameroon, Cote d’Ivoire, Nigeria, Kenya and Togo, similarly to Dogan (2014) in the case of Benin, Congo and Zimbabwe. In the West African Economic Community, Ouedraogo (2013) claims a causality running from GDP to energy, while Kebede et al. (2010) point out regional disparities in energy demand and Wesseh and Lin (2016) work out the role of capital, labor, renewable and non-renewable energies in driving economic performance in Africa. It is to observe that these works on SSA countries are characterized by very limited samples in addition to providing less evidence of an EKC.

In a slightly different perspective, researchers analysed the energy-income relationship, challenging the existence of an Environmental Kuznets Curve (EKC) for energy.¹ This is the case in empirical works by List and Gallet (1999), Nguyen-Van (2010) and Antonakakis et al. (2017), among others. While conflicting, this literature largely does not support the EKC hypothesis.² Thus, in thorough discussions of stylised facts on the energy-income nexus from 1971 to 2010, Csereklyei and Stern (2015); Csereklyei et al. (2016) find a stable increasing relationship over the last four decades coupled with a decreasing energy intensity of GDP (Rühl et al., 2012). Definitely, besides global convergence in energy intensity, there seems to be no doubt that increases in energy consumption are largely driven by economic growth.

1. The EKC suggesting that environmental issues reverse their trend along with economic development.

2. See the work by Tiba and Omri (2017) for a recent literature review on the EKC for energy consumption.

Further relevant aspects of the literature concern drivers of energy use and the channels through which energy availability enhances GDP growth. On the latter point, Toman and Jemelkova (2003) and Birol (2007) argue that energy availability supports the improvement of health and education system and also increases productivity in industry and agriculture.

Regarding potential drivers of energy use, Medlock and Soligo (2001) explore the role of economic sectors to conclude that industrial, transportation and residential energy demand substantially increases at early stage of economic development. Metcalf (2008); Van Benthem and Romani (2009) note end-use prices, the latter authors pointing out the role of agricultural and residential sectors in increasing energy demand in developing countries. Liddle (2013) assesses the relationship between economic growth, urbanization and energy consumption and finds results supporting a long-run relationship between these phenomena. Similar results are observed in the recent study by Dogan and Turkekul (2016), where a cointegration relationship appears between energy, urbanization and trade openness. Finally, in a systematic analysis of the determinants of energy consumption, Azam et al. (2016) mention the significant role played by income level, trade, urbanization, population growth and foreign direct investment.³ Besides the latter socio-economic drivers, very few are research papers addressing the role of institutional and geographical characteristics in energy consumption.

Based on this literature review, recurrent determinants such as per capita GDP, industrial and agricultural production, urbanization, population growth, trade openness and foreign direct investments (FDI) should be accounted for in our empirical analysis.

3. DATA AND DESCRIPTIVE STATISTICS

Assessing how political institutions and geographical characteristics affect primary energy use, we intend to control for the most recurrent energy drivers identified in existing studies along with some SSA contextual elements derived from the comparative development literature. For this purpose, we have drawn socio-economic variables from the World Development Indicators, data on primary energy use from the U.S. Energy Information Administration and indicators of political institutions from the Worldwide Governance Indicators (WGI). Due to missing values, the sample is reduced to 42 SSA countries observed between 1990 and 2013.

Dependent variable: As indicator of energy consumption, this study exploits the total primary energy use expressed in kilo-joules (Kj) per capita. It is to admit that such a synthetic measure of primary energy consumption does not provide any information concerning its composition or renewable structure. However, it serves as a good proxy for fossil and biomass energy use across SSA.

Explanatory variables: Considering socio-economic indicators, almost every empirical study on energy consumption mentioned per capita GDP, trade, population dynamics, urbanization and end-use prices as driving energy demand. Therefore, our study accounts for per capita GDP (in purchasing power parity, PPP in 2011 \$), the shares of imports and exports in GDP, as well as population density and urban population share. Following existing studies on the role of economic sectors in energy demand, the shares of agriculture, industry and FDI (net inflows) in GDP are additionally considered. Also, our dataset includes indicators of political institutions, (index of “governance effectiveness” and “regulatory quality”), poverty levels differentiation (poverty gap and Gini index), social conflicts (violent events and fatalities) and weather differentials (rainfalls and average temperatures) across SSA countries. Data on end-use prices being hardly available for SSA coun-

tries, we rely on average fuel pump price (GIZ data) as proxy for energy price, the latter, however, does not perfectly reflect the prices of primary energy use.⁴

Besides Figure 1 which helps identify Gabon, South-Africa and Nigeria as countries with the highest intensities of primary energy use per capita and respectively Chad, Mali and Ethiopia with the lowest levels, Table 1 reports descriptive statistics of our data for the entire sample. In addition to the series reported in Table 1, the dataset includes further variables such a coastal location dummy, the origin of the colonizer and the year of independence of each SSA country.⁵

Although very insightful, Figure 1 and Table 1 do not provide any information about the geographical distribution of income and urban population across SSA. To fill that gap, we jointly compare income, energy use and urban population share for the 42 countries of our sample (Figure 2). Therein, peaks (respectively low points) in urban population, per capita GDP and energy use are simultaneously observed in the same countries, giving hints on possible links between these phenomena. For instance, peaks are jointly observed in Botswana, Cameroon, Rep. Congo, Gabon, Nigeria, South Africa and Zimbabwe and reciprocally in Benin, Burundi, Chad, Gambia, Mozambique, Niger, Swaziland, Togo and Zambia, where the lowest levels in energy, income and urban population are concurrently noticed. If there is a relationship between these phenomena, genuine data analyses will help assess it. For this purpose, we next present our spatial econometric specification.

Table 1: Descriptive statistics

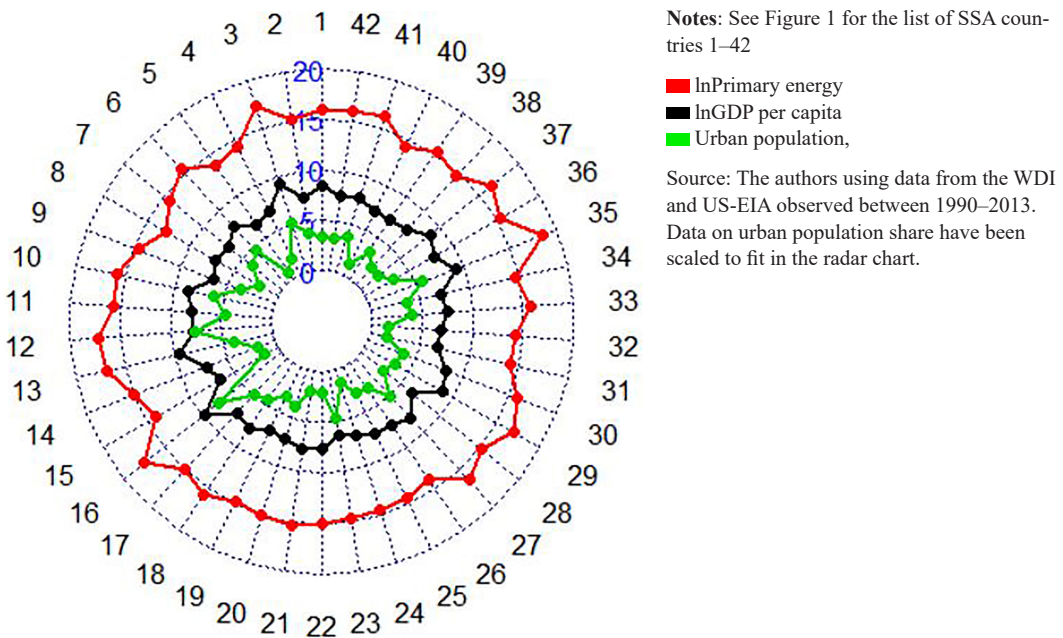
Variables	Units	Mean	S.D	Min	Max	Obs.
lnEnergy use per capita	kilojoule	15.353	1.206	12.616	18.622	1008
lnGDP per capita	ln \$	7.602	0.889	5.508	10.832	1008
Institutions (governance eff.)	index	-.773	.569	-1.982	.876	1008
Institutions (regulatory quality)	index	-.711	.603	-2.412	.791	1008
Agriculture, added value	% GDP	28.062	17.021	.892	78.654	1008
Industry, added value	% GDP	27.267	15.804	3.329	84.283	1008
FDI, net inflows	% GDP	4.249	10.582	-82.892	161.823	1008
Imports	% GDP	44.247	36.059	7.066	424.817	1008
Exports	% GDP	30.834	19.733	3.335	124.393	1008
Population density	count/km ²	57.257	70.442	1.719	449.051	1008
Population growth	%	2.600	1.040	-6.343	7.989	1008
Urban population share	%	34.887	16.142	5.416	86.658	1008
Mean years of education	years	3.905	1.903	.700	10.100	965
Conflicts fatalities	in 1000	.645	4.593	0	77.035	714
Violent events	in 1000	.057	.127	0	1.321	714
Rainfalls, yearly	in dm	10.259	6.018	.704	32.822	966
Average temperatures	°C	24.731	3.286	12.628	29.541	966
Gini index	index	43.963	7.314	29.8	65.8	567
Poverty gap at 1.9\$ a day	% of poverty line	19.604	12.046	1.8	63.6	639
Pop. with electricity access	%	24.705	2.075	.010	89.30	995
Fuel price (average pump price)	ln \$	.855	.405	.020	2.540	941
Urban pop. access to electricity	%	51.604	25.211	.010	100	1006
Government final consumption	% GDP	85.661	24.870	7.693	241.974	1008
Gross fixed capital formation	% GDP	20.132	8.774	-2.424	59.723	1008
Natural resources rents	% GDP	14.851	14.571	.374	89.002	1008

Notes: The sample includes $n = 42$ SSA countries, number of periods $T = 24$, number of observations $nT = 1008$.

4. We thank an anonymous reviewer for this suggestion.

5. The origin of the colonizers and the years of independence will serve as instrument for current institutions.

Figure 2: Mean Income, primary energy use and urban population



4. ECONOMETRIC MODEL

Primary energies being essentially fossil energies (oil, coal and natural gas), we argue that observations on country-level primary energy use are likely subject to spatial spillovers. Moreover, Figure 1 indicates that location matters to energy use in SSA along with the fact that countries with low intensities are mostly surrounded by energy-intensive ones. This suggests accounting for time-invariant spatial effects in primary energy use.

Modelling spatial spillovers, econometric texts (Anselin, 2013; Anselin and Arribas-Bel, 2013; Arbia, 2014) discuss convenient methods that exploit different geographical links and weighting systems. Let $\omega_{(n \times n)}$ be a connectivity matrix (row standardized), the component of which are w_{ij} with $i, j = 1, 2, \dots, n$, a general form of the spatial panel data model is:⁶

$$y_{it} = \mu_i + \rho \sum_{j=1}^n w_{ij} y_{jt} + \sum_{j=1}^n w_{ij} x'_{jt} \beta_w + x'_{it} \beta + u_{it}, \quad \text{with } |\rho| < 1 \tag{1}$$

$$u_{it} = \delta \sum_{j=1}^n w_{ij} u_{jt} + \varepsilon_{it}, \quad \text{with } \varepsilon_{it} | x_{it} \sim iid(0, \sigma^2) \quad \text{and } |\delta| < 1 \tag{2}$$

where ρ, δ, β_w and β are the parameters to estimate, μ_i being the individuals time-invariant characteristics.⁷ $\sum_{j=1}^n w_{ij} y_{jt}$ is the spatial lag of the dependent variable and technically stands for the average energy use in the neighbouring countries, while $\sum_{j=1}^n w_{ij} u_{jt}$ and $\sum_{j=1}^n w_{ij} x_{jt}$ respectively stand for residuals spatial heterogeneity and the spatial lag of the vector of regressors. The parameter ρ captures

6. We use a common border principle and on the k -nearest algorithm for ω . See Tables AM-2 and AM-3.

7. This is the most general model. (1) and (2) assume spatial autocorrelations only in the idiosyncratic term. Models where both, u_{it} and μ_i are spatially correlated are also feasible. See Kapoor et al. (2007).

the strength of the spatial dependence on the neighbouring countries, if spatial spillovers there are in primary energy use. When specification tests (spatial dependence and Robust LM tests) suggest including only $\sum_{j=1}^n w_{ij}y_{jt}$ and $\sum_{j=1}^n w_{ij}u_{jt}$ into the model, equations (1) and (2) become a model combining a spatial autoregressive model with spatially autocorrelated disturbances (SARAR). In that case, the regression model is reduced to:

$$y_{it} = \mu_i + \rho \sum_{j=1}^n w_{ij}y_{jt} + x'_{it}\beta + u_{it} \quad \text{and} \quad u_{it} = \delta \sum_{j=1}^n w_{ij}u_{jt} + \varepsilon_{it}, \quad (3)$$

with $|\rho| < 1$, $|\delta| < 1$ and $\varepsilon_{it} | x_{it} \sim iid(0, \sigma^2)$.

The regression model (3) is the specification we use relating primary energy use to an index of political institutions, income per capita and other determinants.⁸ Estimating ρ , δ , and the vector of parameters β , econometric texts discuss a two steps maximum likelihood (ML) approach, which are proven to provide consistent estimates (Elhorst, 2010; Baltagi et al., 2007; Kelejian and Prucha, 1999; Yu et al., 2008; Debarys and Ertur, 2010).⁹

5. RESULTS AND DISCUSSION

5.1 Modelling primary energy use: Preliminary tests

Fixed-effects versus random-effects models: To begin, we perform a standard Hausman test to compare fixed effects (FE) to random effects (RE) models using seven (7) different specifications. The test results (Table A-1) mostly indicate that FE models consistently match the data generating process. Next, we address endogeneity issues related to the presence of per capita GDP, institutional characteristics and electricity access among regressors.

Addressing endogeneity: Existing studies largely suggest a bidirectional causality between GDP and energy use. The latter being input in production activities (Wolde-Rufael, 2009; Esso, 2010), income level reversely depends on energy use, leading to inverse causality. Regarding institutions, the comparative development literature shows that in former colonies and resource-rich countries such as SSA, current institutions directly derive from colonial institutions, which in Africa mainly appear to be resource extractive institutions (Acemoglu et al., 2001). Thus, current political institutions in former colonies are linked to the origin of the colonizers and highly reflect natural resources extraction strategies.

Solving for endogeneity, we rely on instrumental variables technique. Doing so, as instruments for lnGDP per capita, we use its one year lag, the gross domestic fixed investment and the government final consumption in GDP. Reciprocally, as instruments for current institutions, we use a categorical variable for the origin of the colonizers, the year of independence and the one year lag of resources rents in GDP (proxy for richness in resources). Similar to the previous two variables, introducing access to electricity among the drivers of primary energy use also creates endogeneity as electricity production in SSA largely exploits primary energies. Access to electricity being predominantly a urban phenomenon in Africa, we, therefore, need an instrument which is correlated with the share of population having access to electricity and does not drive current energy use. As a result, we use the one-year lag of urban population share having access to electricity.

8. Equation (3) is actually derived from specification tests, see Tables A-4 and A-5 for more details on the tests. Moreover, the condition $|\rho| < 1$ is known as the stationarity condition.

9. A very comprehensive presentation of these estimation procedures is presented by Millo and Piras (2012).

Concretely, this consists of using predicted values of the endogenous regressors from the first stage regressions in the second stage model. The results of the first stage regressions as well as those of estimating standard FE models are reported in the Appendix (Tables A-2 & A-3) and give first insights into the role of political institutions, geographical factors and income, among others, in primary energy use in SSA. In the remaining, arguing that primary energy use is subject to spatial interactions, we test for spatial correlation and propose a spatial regression analysis.

Evidence of spatial dependence in primary energy use: Firstly, tests for spatial dependence are performed in each of the 24 yearly waves of the dataset using as weighting system a common borders-based connectivity matrix ω^* (see in Additional Materials, Table AM-2). The tests results show evidence of spatial dependence in primary energy use (Table A-4). Secondly, we consider the seven (7) different model specifications, testing for spatial dependence in energy use and in the residuals applying robust LM tests (Baltagi et al., 2007; Anselin, 2013). The latter tests support the presence of spatial spillovers in primary energy use as well as some residuals spatial autocorrelation (Table A-5). Finally, modelling primary energy use in SSA, both spatial lag and residuals spatial autocorrelation should be considered.

Spatial Hausman tests: Accounting for the previous results, we perform spatial Hausman tests, in addition to the standard case. The spatial Hausman tests strengthen the accuracy of the fixed-effects (FE) modelling largely suggested by early results. The latter test results are also reported in Table A-5.

5.2 Results of estimating spatial FE models for primary energy use

Subsequent to the preliminary tests, we estimate the parameters of spatial models of primary energy use, combining ML and instrumental variables method for regressors' endogeneity. At the first stage, we regress per capita GDP and the indicator of political institutions on their respective instrument, as mentioned above, in addition to the remaining set of explanatory variables. Exploiting the predicted values at the second stage, a two-step ML approach following Baltagi et al. (2007) and Millo et al. (2012) is applied to estimate the model' parameters. Due to spatial interactions, we also compute the corresponding total impacts. Indeed, the first part of Table 2 displays the model coefficient, which correspond to average direct impact of the regressors.

Comparing information criteria (AIC), our results interpretation is mainly based on the FE SARAR specification VII. The parameter $\hat{\rho}$ reflects spillovers from the neighbouring countries in energy use. However, as the amplitude of spatial spillovers depends on the weighting system, it should be carefully interpreted. Since the weighting matrix ω^* simply indicates whether countries share a common boundary or not, $\hat{\rho}$ then tells us how on average a country's own level of energy use depends on primary energy consumption in the neighbouring countries, all things being equal. This indication of positive geographical spillovers supports our assertion relatively to the role of geography in primary energy use.¹⁰

Apart from geographical spillovers in primary energy use, the regression model delivers further interesting results concerning the role of political institutions, per capita GDP and openness to trade among others. Regarding political institutions, known in the existing literature as a fundamental cause of long-run economic growth (Acemoglu et al., 2005, 2008), they are expected to be positively driving energy use. By encouraging investments in technology, physical capital and by driving economic outcomes, political institutions enhance energy demand. Accordingly, our esti-

10. Neighbouring SSA countries sharing similar geographical characteristics, also have comparable endowments in energy resources and likely have correlated intensities in fossil energy use.

Table 2: ML estimation of FE-SARAR models of primary energy use (using ω^*)

Covariates	I	II	III	IV	V	VI	VII
$\hat{\rho}$	.047 (.073)	.108* (.067)	.181*** (.062)	.211** (.087)	.249*** (.091)	.254** (.121)	.229** (.115)
$\hat{\delta}$	.027 (.086)	-.054 (.083)	-.172** (.082)	-.253** (.113)	-.309*** (.116)	-.253* (.158)	-.225 (.147)
lnGDP per capita	.765*** (.032)	.779*** (.033)	.676*** (.038)	.732*** (.063)	.730*** (.067)	.488*** (.093)	.445*** (.102)
Institutions	.256*** (.070)	.341*** (.068)	.285*** (.085)	.389*** (.077)	.408*** (.082)	.968*** (.096)	1.085*** (.116)
Agriculture, GDP share		.010*** (.002)	.008*** (.002)	.005* (.003)	.002 (.003)	.012** (.003)	.016*** (.003)
Industry, GDP share		.011*** (.002)	.010*** (.002)	.009*** (.003)	.005* (.003)	.005 (.003)	.008*** (.003)
FDI, GDP share			-.002** (.001)	-.002* (.001)	-.001 (.002)	-.001 (.002)	.002 (.002)
Imports, GDP share			-.003*** (.000)	-.003*** (.001)	-.003*** (.001)	-.005*** (.002)	-.007*** (.002)
Exports, GDP share			.001 (.001)	-.001 (.002)	.001 (.002)	.012*** (.002)	.014*** (.002)
Population density				-.005*** (.001)	-.006*** (.001)	-.005*** (.001)	-.005*** (.001)
Population growth				.001 (.017)	.017 (.018)	-.013 (.016)	.004 (.018)
Urban population share				.005 (.005)	.006 (.005)	.004 (.007)	.007 (.008)
Mean years of education				.017 (.029)	.013 (.029)	-.050 (.038)	-.080** (.041)
Conflicts fatalities					.024 (.021)	-.076** (.027)	-.063* (.027)
Violent events					.273** (.113)	.927*** (.136)	1.033*** (.146)
Rainfalls, yearly					.121* (.065)	.238* (.071)	.229*** (.074)
Average temperature					.023 (.029)	-.010 (.027)	-.024 (.029)
Gini index						-.013* (.003)	-.016*** (.004)
Poverty gap, 1.9\$ a day						.009** (.002)	.010*** (.002)
Access to electricity						.011*** (.004)	.012*** (.004)
LnFuel pump price							.196*** (.041)
Number of obs.	1008	1008	1008	756	714	429	418
Number of countries	42	42	42	42	42	39	38
AIC criterion	3546.276	3510.416	3467.312	2291.08	2100.623	779.704	774.940
Log Likelihood	-1726.138	-1706.208	-1681.656	-1089.540	-990.312	-329.852	-327.470

(continued)

Table 2: ML estimation of FE SARAR models of primary energy use (using ω^*) (continued)

Covariates	I	II	III	IV	V	VI	VII
Total impacts							
In GDP per capita	.803*** (.072)	.873*** (.076)	.826*** (.080)	.928*** (.135)	.971*** (.142)	.654*** (.157)	.578*** (.161)
Institutions	.270*** (.081)	.382*** (.082)	.349*** (.091)	.494*** (.117)	.543*** (.128)	1.298*** (.246)	1.407*** (.281)
Agriculture, GDP share		.011*** (.003)	.009*** (.003)	.006* (.004)	.003 (.003)	.017*** (.005)	.020*** (.005)
Industry, GDP share		.012*** (.002)	.013*** (.002)	.012*** (.004)	.007* (.004)	.007* (.004)	.011** (.004)
FDI, GDP share			-.002** (.001)	-.003* (.001)	-.002 (.002)	-.002 (.003)	.003 (.003)
Imports, GDP share			-.004*** (.001)	-.003*** (.001)	-.004*** (.001)	-.007** (.002)	-.009*** (.003)
Exports, GDP share			.002 (.002)	-.001 (.002)	.001 (.002)	.016** (.004)	.018*** (.004)
Population density				-.007*** (.001)	-.007*** (.001)	-.006*** (.002)	-.007*** (.002)
Population growth			.011 (.024)	.011 (.024)	.024 (.026)	-.017 (.024)	.006 (.024)
Urban population share			.007 (.006)	.007 (.006)	.007 (.007)	.006 (.010)	.009 (.010)
Mean years of education			.021 (.037)	.021 (.037)	.018 (.041)	-.068 (.054)	-.104** (.057)
Conflicts fatalities					.032 (.029)	-.103** (.040)	-.082* (.039)
Violent events					.364** (.164)	1.243*** (.268)	1.340*** (.302)
Rainfalls, yearly					.161* (.089)	.319* (.104)	.296*** (.113)
Average temperature					.030 (.039)	-.013 (.038)	-.031 (.041)
Gini index						-.017* (.005)	-.020*** (.006)
Poverty gap, 1.9\$ a day						.012** (.003)	.013*** (.004)
Access to electricity						.015** (.006)	.015** (.006)
InFuel pump price							.254*** (.069)

Notes: Dependent variable is log primary energy use per capita. As proxy for "Institutions", we use the "Governance effectiveness index" (WGI). For the estimated parameters, bootstrapped standard errors in brackets. Regarding the impact measure, Monte Carlo simulations based total impacts and corresponding standard deviations are reported. $\hat{\rho}$ and $\hat{\delta}$ respectively stand for the spatial effects in primary energy use and in residuals. ***, ** and * respectively indicate significance at 1%, 5% and 10% levels.

mates show positive and significant effects, implying that governance effectiveness, a good policy formulation and implementation enhances the demand for primary energy. Obviously, not only good political institutions shape economic production, they also appear to be enhancing energy use in SSA countries.

Concerning income, the existing literature on SSA (Akinlo, 2008; Wolde-Rufael, 2009) consistently mentions a positive link to energy. Our standard FE (Table A-2) and the FE-SARAR specifications confirm this finding. Considering the structure of the economy, agricultural and industrial production in GDP appear to be positively linked to primary energy use (Medlock and Soligo, 2001). These results indicate that despite being at early stages of development, production activities drives primary energy use in SSA countries.

Controlling for population dynamics, we rely on population growth, urban population share and population density, the latter showing a negative link to energy consumption. This negative link of population density, previously suggested by the standard FE models, seems understandable as increases in total population, translated by positive changes in population density, should also dilute primary energy use measured in per capita terms. However, such an observation is not necessarily true when country level dynamics of energy demand and population are considered. Indeed, increases in total population, thereby in population density, lead to increases in the demand for energy. Energy consumption essentially being a urban phenomena in SSA (Mkhwanazi, 2003), the urban population parameter sheds light on the role of urbanization and population dynamics by indicating a positive link to energy use. Population growth, migration towards urban areas and city enlargement likely intensify the energy demand and consequently primary energy use. A focus on the energy and urban population (and its access to electricity) nexus will help be more conclusive on the role of urbanization. Moreover, openness to international trade assessed using exports, imports and net inflows FDI share in GDP shows that foreign direct investments do not fundamentally promote energy consumption, while exports are found to be driving primary energy use. The latter result, in the context of SSA countries, can probably be extended to other natural resources to argue that SSA economies rely on extracting and exporting natural resources.

The regression model includes further control variables such as weather differentials (temperatures and rainfalls), social conflicts indicators (counts of conflict fatalities and violent events) and indicators of poverty level differentiation (Gini index and poverty gap). In contrast to average temperatures and yearly rainfalls, conflicts fatalities and more largely conflicts severity and civil wars appear to be negatively linked to the energy use per capita. Accounting for poverty incidence and income distribution (Gini index), our analysis shows that the higher income inequalities, the lower primary energy use per capita. Also, population access to electricity positively drives primary energy use. Such a result seems predictable, since electricity production in SSA largely exploits oil, gas and coal sources (primary energies), the latter sources representing more than 65% of total electricity production in SSA between 1990 and 2013.¹¹ Finally, controlling for end-use price by relying on average fuel price, we observe a positive price elasticity of energy, suggesting that an increase in fuel price will boost primary energy use. Evidently, energy is a basic or essential consumption good (i.e Giffen good) in SSA countries.

Conclusively, after controlling for aggregate production, population dynamics, income distribution, poverty incidence, weather differentials and unrest among others, our spatial analysis so far shows that besides geographical spillovers, institutions drive energy use. Indeed, geography and institutions do not only affect economic development, they also drive energy demand.

11. See the World Bank Data on electricity production in SSA from oil, gas and coal sources.)

6. ROBUSTNESS, ROLE OF GEOGRAPHICAL LOCATION AND FUNCTIONAL FORMS

6.1 Robustness check

To check our results for robustness, we apply the same procedures as above by exploiting a different weighting system, a different proxy for political institutions and introducing the same control variables into the model. Thus, this section considers a distance-based weighting system, ω^{**} , which exploits the k -nearest neighbouring algorithm and implies that even not directly contiguous countries could be considered as neighbours by the matrix entries (see Table AM-3). As proxy for institutions, we now use the “*Regulatory Quality Index*”. Moreover, as above, control variables relatively to aggregate economic production, demographics, income distribution, conflicts and access to electricity are considered.

The preliminary test results exploiting the weighting matrix ω^{**} , tests for geographical dependence in each of the 24 waves of the panel dataset, are largely compatible with the previous ones in stressing the importance of accounting for spatial dependences when modelling primary energy use. Given these test results, we estimate the parameter of the regression model (3), with ω^{**} as weighting system, by combining ML and instrumental variable method as above. The results of estimating the different specifications of spatial models of primary energy use are reported in Table 3.

The outcomes of the regression analysis using ω^{**} are quite consistent with the first results, observing the sign, the amplitude and the statistical significance of the parameters of interest. Concerning the ω^{**} -based geographical spillovers, slightly higher amplitudes are noticeable. This is understandable, given its characteristics (higher average number of links) and differences between the two weighting matrices ω^{**} and ω^* . In addition to the geographical effects, political institutions and income per capita, positively and significantly affect energy use, supporting once more our claim on the two sides of the same coin role played by institutions and geography in primary energy use.

Observing the estimated parameters of the control variables, one can definitely argue that FDI, conflicts severity (fatalities) and inequalities in income distribution do not systematically enhance primary energy use in SSA, while exports and population access to electricity significantly do. Again, fuel price positively and significantly drives primary energy use. Globally, the robustness check of our spatial regression analysis relying on a different weighting system and a different indicator of political institutions, namely the regulatory quality index, yields results supporting our first conclusions.

6.2 Does location matter to primary energy use?

The evidence of spatial spillovers in primary energy use partly answers questions concerning the role of geographical characteristics. Also, observing that coastal countries are more energy-intensive and further show relatively high-income levels (Figures 1 and 2), we argue that location might not be neutral in natural resources endowments and extraction, especially in primary energy use. Therefore, we explore the role of location, employing a dummy variable relative to coastal location (1 if coastal located, 0 otherwise) using a standard random panel data model, as the latter does not apply prior individuals time-demeaning transformation to the data.

The results (Table A-2) show that compared to inland countries, being a coastal located country fosters primary energy use per capita. Such a result is not surprising since in average coastal

Table 3: Estimation of FE SARAR models of primary energy use (using ω^{})**

Covariates	I	II	III	IV	V	VI	VII
$\hat{\rho}$	.220*** (.064)	.205** (.067)	.272*** (.064)	.269*** (.082)	.294*** (.083)	.320*** (.135)	.269** (.124)
$\hat{\delta}$	-.165* (.102)	-.117 (.102)	-.219* (.106)	-.261* (.133)	-.323*** (.139)	-.286 (.216)	-.286 (.186)
lnGDP per capita	.737*** (.034)	.755*** (.033)	.640*** (.040)	.660*** (.059)	.668*** (.065)	.520*** (.095)	.502*** (.103)
Institutions	.234*** (.080)	.512*** (.071)	.451*** (.069)	.650*** (.077)	.759*** (.090)	.861*** (.091)	1.024*** (.116)
Agriculture, GDP share		.010*** (.002)	.007*** (.002)	.005** (.002)	.001 (.003)	.011*** (.003)	.016*** (.003)
Industry, GDP share		.011*** (.002)	.011*** (.002)	.014*** (.002)	.010*** (.003)	.009*** (.003)	.010*** (.003)
FDI, GDP share			-.003* (.001)	-.002* (.001)	-.001 (.001)	-.001 (.002)	.002 (.002)
Imports, GDP share			-.002*** (.001)	-.002*** (.001)	-.003*** (.001)	-.002* (.001)	-.006*** (.002)
Exports, GDP share			.001 (.001)	.001 (.001)	.002 (.002)	.008*** (.002)	.013*** (.002)
Population density			-.006*** (.001)	-.006*** (.001)	-.006*** (.001)	-.005*** (.001)	-.005*** (.001)
Population growth				-.035 (.017)	-.030* (.018)	-.042** (.017)	.016 (.017)
Urban population share			.006 (.005)	.006 (.005)	.007 (.005)	.002 (.008)	.001 (.008)
Pop. mean years of edu.			-.022 (.027)	-.022 (.027)	-.039 (.029)	-.086** (.041)	-.053 (.041)
Conflicts fatalities					.040* (.022)	.027 (.029)	-.071** (.027)
Violent events					.429*** (.111)	.555*** (.124)	1.013*** (.147)
Rainfalls, yearly					.177** (.063)	.205*** (.072)	.223*** (.076)
Average temperature					.020 (.026)	-.020 (.028)	-.036 (.029)
Gini index						-.011*** (.003)	-.015*** (.004)
Poverty gap, 1.9\$ a day						.003* (.002)	.009*** (.002)
Access to electricity						.013*** (.004)	.014*** (.004)
LnFuel pump price							.210*** (.043)
Number of Obs.	1008	1008	1008	756	714	429	418
Number of countries	42	42	42	42	42	39	38
AIC Criterion	3522.478	3473.778	3428.418	238.830	2040.929	788.195	780.403
Log Likelihood	-1714.239	-1687.889	-1662.209	-1063.415	-960.4647	-334.097	-330.2013

(continued)

Table 3: Estimation of FE SARAR models of primary energy use (using ω^{}) (continued)**

Covariates	I	II	III	IV	V	VI	VII
Total impacts							
lnGDP per capita	.938*** (.089)	.950*** (.092)	.879*** (.093)	.904*** (.143)	.946*** (.146)	.765*** (.200)	.686*** (.190)
Institutions	.546*** (.114)	.644*** (.103)	.619*** (.112)	.889*** (.158)	1.075*** (.184)	1.266*** (.280)	1.400*** (.307)
Agriculture, GDP share		.012*** (.003)	.011*** (.003)	.007 (.004)	.002 (.003)	.016*** (.005)	.022*** (.006)
Industry, GDP share		.013*** (.002)	.015*** (.003)	.020*** (.004)	.015** (.004)	.013** (.005)	.014*** (.005)
FDI, GDP share			-.004* (.002)	-.003 (.002)	-.002 (.002)	-.002 (.004)	.002 (.004)
Imports, GDP share			-.003*** (.001)	-.003*** (.001)	-.005*** (.001)	-.003* (.002)	-.008*** (.003)
Exports, GDP share			.001 (.002)	.002 (.002)	.003 (.002)	.013*** (.004)	.018*** (.005)
Population density				-.008*** (.001)	-.009*** (.002)	-.008*** (.002)	-.006*** (.002)
Population growth				-.048 (.027)	-.030 (.026)	.063** (.031)	.022 (.026)
Urban population share				.008 (.007)	.007 (.007)	.003 (.012)	-.002 (.011)
Pop. mean years of edu.				.031 (.039)	-.039 (.042)	-.126* (.067)	-.072 (.060)
Conflicts fatalities					.048 (.033)	.039 (.045)	-.097* (.042)
Violent events					.430** (-.176)	.816*** (.243)	1.384*** (.330)
Rainfalls, yearly					.177 (.097)	.302** (.128)	.304** (.124)
Average temperature					.020 (.040)	-.003 (.045)	-.050 (.043)
Gini index						-.016** (.006)	-.021*** (.007)
Poverty gap, 1.9\$ a day						.005* (.003)	.013*** (.004)
Access to electricity						.019* (.007)	.020** (.007)
lnFuel pump price							.287*** (.081)

Notes: Dependent variable is log primary energy use per capita. As proxy for “Institution”, we use the “Regulatory Quality Index” (WGI). ω^{**} is displayed in Table AM-3. For the estimated parameters, bootstrapped standard errors in brackets. Regarding the impact measure, Monte Carlo simulations based total impacts and corresponding standard deviations are reported. $\hat{\rho}$ and $\hat{\delta}$ respectively stand for the spatial effects in primary energy use and in residuals. ***, **, * and * respectively indicate significance at 1%, 5% and 10% levels.

located countries are also the one with intensive agricultural, mining and manufacturing activities. As economic activities appear intensive in coastal located SSA countries, so does energy demand. Based on this, we can fairly state that location matters not only in comparative development but also in energy consumption, supporting that geography matters.

In conclusion, this robustness analysis supports our leading results regarding the potential for good political institutions and geographical characteristics in driving primary energy use. Furthermore, it helps fully highlight the role of aggregate economic production, income inequalities, access to electricity, conflicts severity and exports in energy consumption.

6.3 The primary energy use, income and urbanization nexus

Supplementary to the robustness analysis, we test for linearity in the relationship between income, urban population and primary energy use in SSA. The purpose of this exercise is to provide general patterns of the links between these phenomena. Consequently, we rely on the local constant or Nadayara-Watson kernel estimator. This approach clarifies the details by indicating an overall upward functional form between income per capita and primary energy use. Such a result helps indeed draw conclusions regarding the non-existence of an EKC for primary energy use in SSA (Figure 3).

To closely investigate the general pattern of the link between population dynamics, urbanization and primary energy consumption, it is quite informative to focus on urban population share in total population and its access to electricity. This not only because parametric specification could be misleading but also because energy consumption being mainly an urban phenomenon in Africa (Mkhwanazi, 2003; IEA Outlook, 2014), considering urban population share and its access to electricity should provide mostly informative outcomes.

The results of the local constant kernel estimator (Figure 3, Panel B & C) show increasing patterns in primary energy use to urban population share and its access to electricity. Accurately, while access to electricity overall positively drives primary energy use, for a share of urban population up to 60% a significantly clear upward trend appears. These results indicate that urban population growth and related phenomena (city enlargement and growing electrification) in SSA lead to higher demand for energy. Consequently, increases in primary energy use are to foresee in SSA countries where rapid urban population growth and economic growth are being observed.

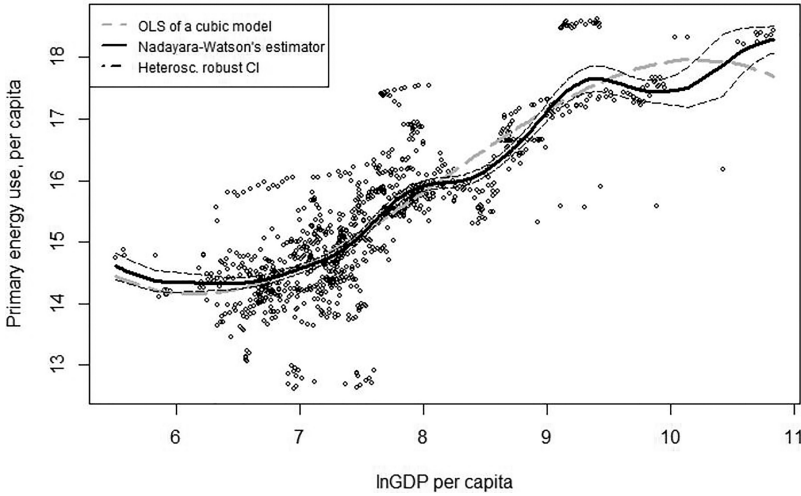
7. CONCLUDING REMARKS

The existing literature on energy consumption has essentially focused on direction of the causality between energy and income, the existence of an EKC for energy use, and further on the social and economic drivers of energy consumption. In SSA, where population and economic activities are rapidly growing, the existing studies have also raised questions on the determinants of fossil energy use and future energy demand. Contrary to studies on comparative development, issues related to the role of institutions and geography in energy use are much less regarded, whereas it is underlined that geographic variations dictate societies' fates (Diamond, 1999). Evidently, this paper does not aim at assessing how biogeographic variations govern social organizations. But, by drawing upon the well-known Institutions versus Geography debate, we argued that while both institutions and geography affect energy use through economic growth (indirect channel), they also matter for energy use (direct channel) in SSA countries.

The results of our empirical analysis support the existence of geographical spillovers in primary energy use among SSA countries, probably induced by natural endowments in energy re-

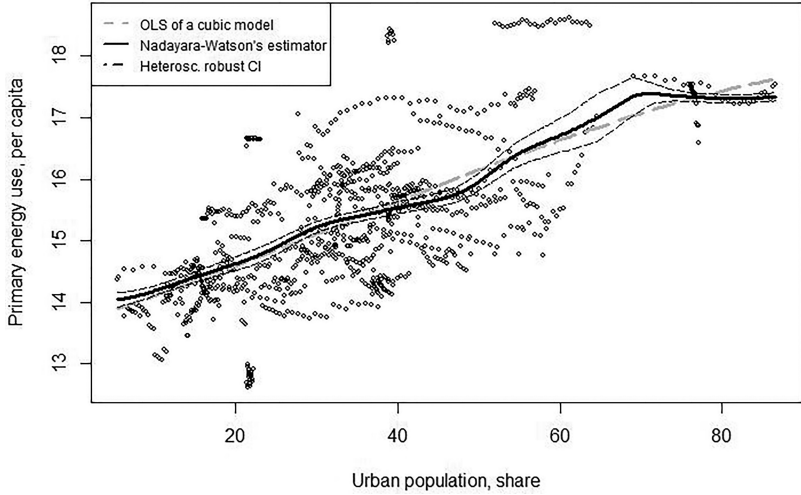
Figure 3: Functional forms of income per capita, urban population and electricity access

Panel A

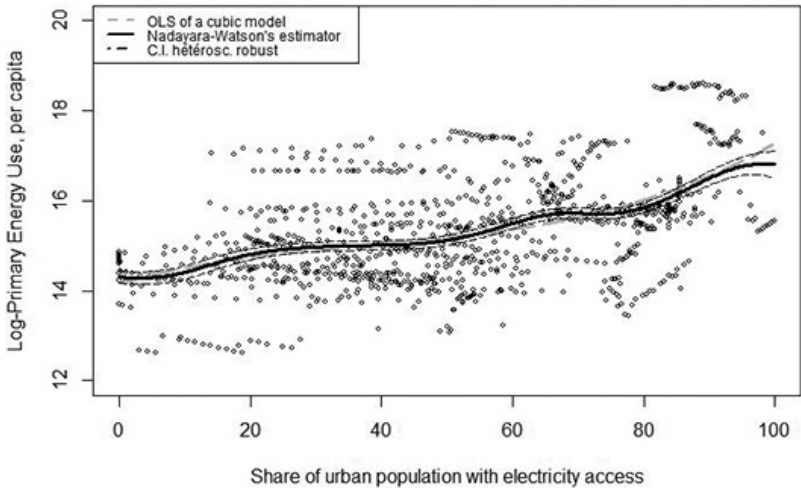


Notes: The black curves are the NW-estimator and its 95% confidence interval. As bandwidth parameter, we rely on Silverman's rule of thumb, since the latter works well for approximately normal densities.

Panel B



Panel C



sources and cooperation in energy sectors. This somewhat highlights the role of geography in energy use, by suggesting that in SSA a country's own level in energy use is positively affected by primary energy use in the neighbouring countries. In addition to the spatial interactions, SSA coastal countries mostly showing higher income level also appear to be relatively more energy intensive than inland ones. Indeed, coastal location appears to foster economic activities (international trade, fishing and agricultural production, etc.) and then to enhance energy use, supporting our argument that geography matters. Similar to geographical location, good political institutions are also found to be enhancing primary energy demand in SSA, illustrating a "two sides of the same coin" role by institutions and geography.

Furthermore, our results show that income per capita and urban population positively drive primary energy use, implying that future economic performances and urbanization in SSA will lead to higher demands for energy. This is currently the case in South-Africa, Gabon, Nigeria, Equatorial Guinea and Ghana where economic performances and urbanization coincide with intensive primary energy use. As our sample is constituted by pre-industrial countries, thus low income countries, growing fossil energy consumption and related environmental consequences such as pollutants emission are to expect in the near future. On the role of population dynamics in SSA countries, as projections point to a fast population growth over the next 50 years, increases in the demand and growth of fossil energy use are also to expect, making Sustainable Development Goals more difficult to achieve in Africa.

This study on the role of institutions and geography in primary energy use across SSA exploiting spatial regression approach has let some important points open to discussion and possible improvements, especially concerning the environmental consequences of fossil and biomass energy use in pre-industrial economies. A further very insightful extension of this paper could be to purely investigate the primary energy consumption and carbon dynamics at early stages of development, by focusing on Sub-Saharan African countries. This can be a task for a future research.

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APPENDIX**Table A-1: Standard Hausman test**

Hausman-test Stat.	χ^2	<i>p</i> -value	Number of regressors	NT
Model I	29.458	4.0e-07	2	1008
Model II	28.119	1.1e-05	4	1008
Model III	27.800	2.4e-04	7	1008
Model IV	5.792	.887	11	756
Model V	36.266	.002	15	714
Model VI	61.177	1.4e-06	18	429
Model VII	40.076	.003	19	418

Notes: See Table 6 below for the variables involved in Models I-VII.

Table A-2: Result of standard instrumental variables models of primary energies use

Covariates/Models	FE-I	FE-II	FE-III	RE-IV	FE-VI	FE-VI	FE-VI	RE-VI+location	RE-VII+location
lnGDP per capita	.769*** (.037)	.788*** (.037)	.694*** (.036)	.737*** (.382)	.781*** (.092)	.512*** (.124)	.511*** (.072)	.519*** (.095)	.674*** (.123)
Institutions	.259*** (.109)	.334*** (.116)	.272*** (.105)	.410*** (.055)	.449*** (.132)	.630*** (.189)	.646*** (.159)	.008** (.003)	.004 (.003)
Agriculture, GDP share	.009*** (.003)	.007** (.003)	.006** (.003)	.006** (.003)	.004 (.003)	.009** (.004)	.006** (.003)	.002 (.003)	.004 (.003)
Industry, GDP share	.010*** (.002)	.010*** (.002)	.010*** (.002)	.010*** (.002)	.006** (.003)	.004 (.004)	.002 (.003)	.002 (.003)	.004 (.003)
FDI, GDP share		-.002 (.002)	-.002 (.002)	-.002 (.002)	-.001 (.002)	-.001 (.003)	-.002 (.003)	-.002 (.003)	-.001 (.003)
Imports, GDP share		-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.004** (.002)	-.003* (.002)	-.003* (.002)	-.004** (.002)
Exports, GDP share		.001 (.001)	.001 (.001)	-.001 (.002)	.001 (.002)	.006** (.003)	.006** (.003)	.006*** (.002)	.006*** (.002)
Population density				-.004*** (.001)	-.006*** (.001)	-.004*** (.001)	-.004*** (.001)	-.004*** (.001)	-.004*** (.001)
Population growth				-.004 (.017)	.026 (.019)	.001 (.019)	-.005 (.020)	.010 (.020)	.008 (.006)
Urban population share				.010*** (.002)	.007 (.005)	-.004 (.007)	.008*** (.003)	.008 (.006)	.008 (.006)
Mean years of education				.027*** (.016)	.032 (.024)	-.012 (.039)	-.016 (.023)	-.023 (.039)	-.023 (.039)
Conflicts fatalities					.023 (.039)	-.080** (.040)	-.076* (.045)	-.068** (.030)	-.068** (.030)
Violent events					.297** (.144)	.697*** (.169)	.741*** (.175)	.785*** (.162)	.785*** (.162)
Rainfalls, yearly					.134 (.088)	.150* (.084)	.069 (.070)	.046 (.086)	.046 (.086)
Average temperature					.034 (.030)	.007 (.032)	-.059*** (.010)	-.064*** (.025)	-.064*** (.025)
Gini index						-.009** (.004)	-.008** (.003)	-.008* (.004)	-.008* (.004)
Poverty gap, 1.9\$ a day						.007*** (.002)	.007** (.002)	.008*** (.002)	.008*** (.002)
Access to electricity						.013*** (.005)	.012*** (.003)	.013*** (.004)	.013*** (.004)
Coastal location dummy							.467*** (.065)	.453** (.212)	.453** (.212)
LnFuel pump price								.088** (.042)	.088** (.042)
Intercept	—	—	—	9.602*** (.402)	—	—	12.629*** (.577)	12.646*** (1.062)	12.646*** (1.062)
Observations	1008	1008	1008	1008	756	429	429	418	418
Number of countries	42	42	42	42	42	39	39	38	38
F-stat (<i>p</i> -value)	301.963 (.000)	166.198 (.000)	105.390 (.000)	59.229 (.000)	30.003 (.000)	7.826 (.000)	15.027 (.000)	272.941 (.000)	272.941 (.000)
Adjusted <i>R</i> ²	.358	.381	.406	.459	.356	.274	.384	.407	.407

Notes: Dependent variable is log primary energy use per capita. As proxy for “Institutions”, we use the “Governance effectiveness index” (WGI). Bootstrapped standard errors are in brackets. ***, ** and * respectively indicate significance at 1%, 5% and 10% levels. As instrument for lnGDP per capita and institutions, we respectively use one year lag lnGDP per capita and share of resource rents in GDP. The location dummy takes 1 if coastal located, 0 otherwise.

Table A-3: Results of first stage regressions surrounding Tables 2 and 3

	Panel A: First stage for GDP per Capita, used in Tables 2 and 3						
Covariates	I	II	III	IV	V	VI	VII
Intercept	.029 (.026)	.104*** (.036)	.109*** (.037)	.068* (.039)	.097** (.046)	.126** (.059)	.076 (.056)
lag.lnGDP p. c.	.997*** (.003)	.985*** (.004)	.989*** (.004)	.995*** (.005)	.990*** (.005)	.978*** (.000)	.983*** (.006)
Gross fixed Cap. form.	.001*** (.000)	.001*** (.000)	.002 (.003)	-.001* (.000)	-.001* (.000)	.007* (.004)	.004 (.003)
Gov. final consumption	-.002* (.001)	.001 (.001)	-.004*** (.001)	-.001*** (.000)	-.001** (.000)	-.002 (.002)	-.003 (.002)
Agriculture, GDP share		-.003 (.002)	-.004** (.002)	-.002 (.002)	-.007 (.027)	-.001 (.002)	.002 (.002)
Industry, GDP share		.008*** (.002)	-.001 (.002)	.008 (.028)	.002 (.003)	.001* (.000)	.009** (.003)
FDI, GDP share			.001*** (.000)	.004 (.025)	-.005 (.003)	.005 (.005)	.005 (.004)
Imports, GDP share			.003*** (.001)	.001*** (.000)	.001*** (.000)	-.003 (.002)	-.002 (.002)
Exports, GDP share			.002 (.002)	-.005** (.002)	-.004 (.003)	.004 (.003)	.002 (.002)
Population density				.023 (.032)	.036 (.035)	.002 (.003)	.028 (.034)
Population growth				.018*** (.003)	.018*** (.003)	.004 (.003)	.003 (.002)
Urban population share				-.088 (.175)	-.037 (.021)	-.005** (.002)	-.006** (.003)
Pop. mean years of education				.004** (.002)	.005** (.002)	.001 (.002)	.001 (.001)
Conflicts fatalities					-.001 (.001)	-.002 (.006)	-.002 (.006)
Violent events					-.056** (.021)	-.061*** (.024)	-.065** (.023)
Rainfalls, yearly					-.004 (.005)	-.001 (.006)	-.003 (.005)
Average temperature					.009 (.101)	-.006 (.011)	-.008 (.010)
Gini Index						.002*** (.000)	.001** (.000)
Poverty gap, 1.9\$ a day						-.007** (.003)	-.008** (.003)
LnFuel pump price							.018** (.007)
Number of obs.	1008	1008	1008	756	714	429	418
Number of countries	42	42	42	42	42	39	38
Adjusted R-squared	.993	.993	.994	.996	.996	.997	.998
F-Stat (p-value.)	4.9e4 (.000)	2.9e4 (.000)	2.0e4 (.000)	1.4e4 (.000)	1.0e4 (.000)	8093 (.000)	8739 (.000)

(continued)

Table A-3: Results of first stage regressions surrounding Tables 2 and 3 (continued)

Panel B: Political institutions: First stage for "Governance effectiveness" (used in Table 2)							
Covariates	I	II	III	IV	V	VII	
Intercept	2.349 (1.588)	12.81*** (1.481)	13.23*** (1.517)	9.44*** (1.796)	10.93*** (1.694)	21.20*** (3.031)	19.98*** (2.931)
lag-Resources rents in GDP	-.018*** (.001)	-.019*** (.001)	-.018*** (.001)	-.020*** (.002)	-.019*** (.002)	-.018*** (.002)	-.017*** (.002)
Year of Independence	-.001* (.000)	-.007*** (.001)	-.007*** (.001)	-.005*** (.001)	-.006*** (.000)	-.011*** (.002)	-.011*** (.002)
Origin of the colonial power (categorical, ref. = not colonized):							
Belgian	-.412*** (.076)	-.317*** (.066)	-.345*** (.068)	-.598*** (.088)	-.404*** (.091)	-.699*** (.129)	-.665*** (.124)
British	.167** (.056)	.010 (.051)	.005 (.051)	-.162** (.056)	-.108* (.053)	-.558*** (.080)	-.537*** (.077)
French	-.006 (.056)	-.119** (.050)	-.121** (.051)	-.002 (.057)	.030 (.054)	-.471*** (.082)	-.341*** (.081)
Portuguese	.081 (.079)	.079 (.069)	.079 (.069)	.132* (.076)	.210*** (.071)	-.190*** (.092)	-.024*** (.097)
Spanish	.072 (.119)	-.447*** (.114)	-.435*** (.120)	-.399*** (.128)	-.061 (.125)	—	—
Agriculture, GDP share		-.016*** (.001)	-.017*** (.001)	-.011*** (.002)	-.002 (.002)	-.005** (.002)	-.007*** (.002)
Industry, GDP share		.001 (.002)	.002 (.002)	.005** (.002)	.011*** (.002)	.012*** (.002)	.006*** (.003)
FDI, GDP share			-.001 (.002)	-.003* (.002)	-.003 (.002)	-.008** (.003)	-.007** (.003)
Imports, GDP share			.003 (.005)	.002** (.001)	.002** (.001)	.006*** (.001)	.007*** (.001)
Exports, GDP share			-.002* (.001)	-.004** (.001)	-.005*** (.001)	-.009*** (.002)	-.008*** (.002)
Population density				.002*** (.000)	.002*** (.000)	.002*** (.001)	.002*** (.000)
Population growth				.041** (.020)	.021 (.027)	.056** (.021)	.041*** (.021)
Urban population share				-.001 (.001)	.002 (.002)	-.003 (.002)	-.001 (.001)
Pop. mean years of education				.091*** (.011)	.101*** (.011)	.107*** (.014)	.109*** (.014)
Conflicts fatalities					.001 (.003)	.022 (.042)	-.027 (.041)
Violent events					-.001** (.000)	-.809*** (.164)	-.634*** (.158)
Rainfalls, yearly					-.031*** (.003)	-.173*** (.039)	-.178*** (.038)
Average temperature					-.007 (.006)	.037*** (.008)	.042*** (.008)
Gini index						.016*** (.003)	.016*** (.004)
Poverty gap, 1.9\$ a day						-.006*** (.002)	-.005** (.002)
LnFuel pump price							-.314*** (.054)
Number of obs.	1008	1008	1008	756	714	429	418
Number of countries	42	42	42	42	42	39	38
Adjusted R-squared	.294	.475	.476	.529	.617	.711	.749
F-Stat (p-value.)	60.88 (.000)	102.10 (.000)	77.08 (.000)	54.03 (.000)	58.36 (.000)	51.13 (.000)	53.61 (.000)

(continued)

Table A-3: Results of first stage regressions surrounding Tables 2 and 3 (continued)

	Panel C: First stage for "Share of population with electricity access", used in Tables 2 and 3						
Covariates	I	II	III	IV	V	VI	VII
Intercept						-3.655*** (6.529)	-3.5.226*** (6.743)
Lag. Share of Urban Population with Elec. access						.465*** (.022)	.461*** (.022)
Agriculture, GDP share						-.167*** (.038)	-.161*** (.040)
Industry, GDP share						-.061 (.064)	-.073* (.045)
FDI, GDP share						-.052 (.067)	-.057 (.067)
Imports, GDP share						-.004 (.025)	-.002 (.026)
Exports, GDP share						-.043 (.035)	-.042 (.036)
Population density						.011** (.005)	.011** (.005)
Population growth						-.354 (.424)	-.485 (.431)
Urban population share						.539*** (.032)	.546*** (.031)
Pop. mean years of education						1.179*** (.273)	1.142*** (.275)
Conflicts fatalities						2.117*** (.841)	2.203*** (.848)
Violent events						-9.173*** (3.085)	-9.614*** (3.107)
Rainfalls, yearly						-.419 (.753)	-.101 (.767)
Average temperature						.428*** (.148)	.478*** (.150)
Gini index						.028 (.037)	.253*** (.064)
Poverty gap, 1.9\$ a day						.228*** (.062)	-.028 (.038)
LnFuel pump price							-.489 (1.069)
Number of obs.	42	42	42	42	42	429	418
Number of countries						39	38
Adjusted R-squared						.904	.904
F-Stat (p-value.)						251.9 (.000)	230.70 (.000)

(continued)

Table A-3: Results of first stage regressions surrounding Tables 2 and 3 (continued)

	Panel D: Political institutions: First rate for "Regulatory Quality" ⁷⁷ (used in Table 3)						
Covariates	I	II	III	IV	V	VI	VII
Intercept	.687 (1.663)	7.869*** (1.697)	8.205*** (1.735)	3.508* (1.990)	4.822** (1.998)	8.621** (3.439)	8.394** (3.501)
lag.Resources rents in GDP	-.016*** (.001)	-.018*** (.002)	-.018*** (.001)	-.022*** (.002)	-.21*** (.002)	-.021*** (.002)	-.020*** (.003)
Year of Independence	-.001 (.001)	-.004*** (.001)	-.004*** (.001)	-.003*** (.001)	-.003** (.001)	-.006*** (.002)	-.005** (.002)
Origin of the colonial power (categorical, ref. = not colonized):							
Belgian	-.275*** (.080)	-.220*** (.075)	-.221*** (.078)	-.393*** (.098)	-.226** (.107)	-.951*** (.145)	-.951*** (.147)
British	.403*** (.059)	.270*** (.058)	.257 (.059)	.103 (.062)	.154* (.063)	-.460*** (.091)	-.464*** (.092)
French	.307 (.058)	.212*** (.056)	.189** (.058)	.419*** (.064)	.453*** (.064)	-.173* (.093)	-.164* (.097)
Portuguese	.172 (.083)	.152* (.079)	.143 (.079)	.317* (.084)	.395*** (.084)	-.159 (.105)	-.099 (.117)
Spanish	.023 (.126)	-.405*** (.130)	-.329** (.137)	-.132 (.141)	.140 (.147)	—	—
Agriculture, GDP share		-.009*** (.001)	-.009*** (.002)	-.003* (.002)	.003 (.002)	-.001 (.002)	-.002 (.002)
Industry, GDP share		.004** (.002)	.003 (.002)	.001 (.002)	.005* (.003)	.011*** (.002)	.010*** (.003)
FDI, GDP share			.001 (.002)	-.001 (.002)	.001 (.002)	-.004 (.003)	-.004 (.004)
Imports, GDP share			-.001* (.000)	-.001 (.006)	-.003 (.007)	.002 (.001)	.003* (.002)
Exports, GDP share			.002* (.001)	-.003** (.001)	.003* (.002)	-.004** (.002)	-.004* (.002)
Population density				.002*** (.000)	.002*** (.000)	.002*** (.000)	.002*** (.000)
Population growth				.087*** (.022)	.078*** (.023)	.111*** (.024)	.104*** (.025)
Urban population share				-.001 (.001)	.001 (.002)	-.002 (.002)	-.002 (.002)
Pop. mean years of education				.138*** (.012)	.142*** (.014)	.147*** (.016)	.149*** (.017)
Conflicts fatalities					-.039 (.037)	-.133*** (.048)	-.141*** (.049)
Violent events					-.614** (.151)	-.325* (.186)	-.321* (.189)
Rainfalls, yearly					-.249*** (.036)	-.175*** (.045)	-.166*** (.046)
Average temperature					-.008 (.007)	.031*** (.010)	.035*** (.010)
Gini index						.014*** (.004)	.015*** (.004)
Poverty gap, 1.9\$ a day						.001 (.002)	.001 (.002)
LnFuel pump price							-.058 (.066)
Number of obs.	1008	1008	1008	756	714	429	418
Number of countries	42	42	42	42	42	39	38
Adjusted R-squared	.308	.385	.393	.495	.539	.652	.665
F-Stat (p-value.)	65.05 (.000)	70.92 (.000)	53.73 (.000)	47.35 (.000)	42.61 (.000)	39.20 (.000)	35.72 (.000)

Notes: Share of population access to electricity appears only in specification VI and has been treated for inverse causality. Furthermore in specification VI, countries colonized by Spain (Equatorial Guinea) are excluded due to missing values. Robust standard errors are in brackets. ***, ** and * respectively indicate significance at 1%, 5% and 10% levels.

Table A-4: Test for spatial dependence in primary energy use considering yearly waves

Wave	using ω^*		using ω^{**}	
	Moran I	<i>p</i> -value	Moran I	<i>p</i> -value
Wave 1990	.087	.155	.091	.059
Wave 1991	.065	.206	.074	.091
Wave 1992	.054	.237	.065	.113
Wave 1993	.052	.241	.062	.120
Wave 1994	.039	.279	.042	.156
Wave 1995	.049	.250	.048	.164
Wave 1996	.025	.326	.035	.210
Wave 1997	.029	.314	.043	.180
Wave 1998	.061	.217	.050	.158
Wave 1999	.083	.164	.064	.115
Wave 2000	.100	.128	.081	.076
Wave 2001	.122	.090	.113	.031
Wave 2002	.179	.031	.109	.036
Wave 2003	.182	.029	.106	.039
Wave 2004	.154	.051	.119	.026
Wave 2005	.216	.014	.138	.014
Wave 2006	.219	.013	.145	.011
Wave 2007	.247	.007	.161	.006
Wave 2008	.276	.003	.196	.001
Wave 2009	.275	.003	.196	.002
Wave 2010	.301	.001	.219	.000
Wave 2011	.275	.003	.198	.001
Wave 2012	.276	.003	.198	.001
Wave 2013	.277	.003	.234	.000

Notes: Moran-I test under randomisation for primary energy use. H_0 is no spatial dependence. Each yearly wave consists of 42 observations. See Table AM-2 and AM-3 for details regarding the weighting systems ω^* and ω^{**} .

Table A-5: Results of preliminary tests

Models specification	I	II	III	IV	V	VI	VII
Robust LM tests for spatial dependence ⁽¹⁾							
In primary energy	12.168 (.001)	16.148 (.000)	14.483 (.000)	20.173 (.000)	25.694 (.000)	4.807 (.028)	2.851 (.091)
In residuals	8.272 (.004)	7.115 (.008)	8.322 (.004)	19.287 (.000)	17.794 (.000)	3.448 (.063)	.376 (.539)
FE vs. RE Spatial Hausman test ⁽²⁾							
χ^2	42.016	88.605	32.817	74.179	32.749	63.385	123.22
<i>p</i> -value	.000	.000	.000	.000	.000	.000	.000

Notes: The test results reported here exploit the borders-based weighting matrix ω^* . ⁽¹⁾Based on the results of standard Hausman tests, we perform locally robust LM tests for spatial lag and spatial error dependences. The statistics are LM-stat and in brackets the corresponding *p*-values. ⁽²⁾Based on the the spatial LM test results, we perform Hausman test comparing FE vs. RE SARAR models. The latter test defines the type of spatial panel data model (FE or RE) to estimate.

ADDITIONAL MATERIALS

Table AM-1: SSA: Colonizers, year of independence and coastal dummy as used in the paper

ID	Countries	Origin of colonizers	Year of independence	Coastal location dummy
1	Angola	Portuguese	1975	1
2	Benin	French	1960	1
3	Botswana	British	1966	0
4	Burkina Faso	French	1960	0
5	Burundi	Belgian	1962	0
6	Cameroon	French	1960	1
7	Central African Rep.	French	1960	0
8	Chad	French	1960	0
9	Congo, Rep.	French	1960	1
10	Cote d'Ivoire	French	1960	1
11	Congo, Dem. Rep.	Belgian	1960	1
12	Djibouti	French	1977	1
13	Equatorial Guinea	Spanish	1968	1
14	Eritrea	Others	1993	1
15	Ethiopia	Others	1947	0
16	Gabon	French	1960	1
17	Gambia, The	British	1965	1
18	Ghana	British	1957	1
19	Guinea	French	1958	1
20	Guinea-Bissau	Portuguese	1974	1
21	Kenya	British	1963	1
22	Lesotho	British	1966	0
23	Liberia	Others	1874	1
24	Madagascar	French	1960	1
25	Malawi	British	1964	0
26	Mali	French	1960	0
27	Mauritania	French	1960	1
28	Mozambique	Portuguese	1975	1
29	Namibia	Others	1990	1
30	Niger	French	1960	0
31	Nigeria	British	1960	1
32	Rwanda	French	1962	0
33	Senegal	French	1960	1
34	Sierra Leone	British	1961	1
35	South Africa	British	1910	1
36	Swaziland	British	1968	0
37	Tanzania	British	1961	1
38	Togo	French	1960	1
39	Uganda	British	1962	0
40	Zambia	British	1964	0
41	Zimbabwe	British	1965	0
42	Sudan	British	1956	1

Figure AM-1: Primary energy use and electricity access across SSA countries between 1990–2013

