Dynamic and spillover effects of armed conflicts on renewable energy choice in Subsaharan Africa

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Abstract

Armed conflicts in sub-Saharan Africa hamper the development of the energy transition by threatening the development of sustainable energy infrastructures. These conflicts cause delays, economic losses, and obstacles to progress, underscoring the need for political stability to foster the energy transition in the region.

In this context, this article uses spatial regression to examine the impact of armed conflict on renewable energy consumption in sub-Saharan Africa. The results show that armed conflicts reduce renewable energy consumption by about 31% and increase fossil energy consumption by 40%. The impact is greater in the Sahel. The impact of terrorism on renewable energy choice is also much greater than other types of conflict.

Keywords : Armed Conflicts, Energy Transition, Dynamic Spatial Regression, Sub-Saharan Africa.

JEL Codes : D74 ;Q43 ;C23 ;N57

1 Introduction

Renewable Energy question is emerging as an unavoidable global imperative, aimed at reconciling economic growth with environmental preservation. While developed countries have taken significant steps to diversify their energy sources and reduce their carbon footprint, developing countries, particularly those in sub-Saharan Africa, find themselves at a crossroads. Faced with pressing socio-economic challenges, such as the fight against poverty, access to energy remains a crucial priority. However, these nations also have the opportunity to choose sustainable energy trajectories, taking advantage of their immense renewable resource potential. Over the past few years, innovative initiatives and international partnerships have emerged, catalyzing substantial changes in the way these countries envisage and approach their energy transition. However, persistent challenges such as financing, infrastructure and governance require a holistic approach and global cooperation to ensure a sustainable energy future for these developing nations. In line with this, the International Energy Agency predicts that global energy demand will increase from 12 billion tons of oil in 2009 to 18 billion tons in 2035(IEA, 2011). In recent years, some alternatives have been developed in response to this high energy demand and in support of a smooth energy transition.

Sub-Saharan Africa's alternative energy sources focus on renewable energy (Atalay et al., 2016) to support the energy transition. These include the massive deployment of solar energy in Ethiopia, the creation of several mini-grids in Kenya and Burkina Faso, and the Malicounda biomass power plant in Senegal, which will produce electricity from agricultural waste and is scheduled to open in 2020. Sub-Saharan Africa is emerging as a leader in the global energy transition. The region's countries understand the critical importance of diversifying their energy sources and reducing their carbon footprints. However, their many efforts to achieve a successful energy transition are hampered by several major challenges (Van den Bergh, 2013). In addition to the factors mentioned above, political instability, particularly that associated with armed conflict, has recently become a major problem in sub-Saharan Africa, putting the energy transition on hold.

In recent years, the world has witnessed several armed conflicts with catastrophic consequences for civilians and countries alike. Among the most prominent conflicts are the wars in Syria, Yemen, Afghanistan, Libya, the Israeli-Palestinian conflict, the recent Russian-Ukrainian conflict, and the rise of multiple armed attacks in sub-Saharan Africa. These armed conflicts caused more than 8,900 deaths and more than 9 million internally and externally displaced people worldwide in 2020, and have had a major impact on the stability and security of these regions (see https ://ourworldindata.org/terrorismwhat-share-of-deaths-are-from-terrorism). This instability has led to an increase in military spending of up to 5% of GDP as in Burkina Faso in 2020, at the expense of investment in energy transition.

In Sub-Saharan Africa, groups such as Boko Haram, Al-Shabaab, Al-Qaida, the Islamic State of the Sahel and other terrorist organizations are conducting operations in the region, using guerrilla tactics and suicide bombings, and forcing populations to undergo multiple displacements. Some countries in the region are experiencing tensions related to ethnic, tribal or religious differences, with conflicts between groups such as nomadic herders and sedentary farmers. In addition, elections, putsch and popular uprisings can trigger tensions and violence, with disputes over the results of elections or the electoral process itself. Some countries, such as the Democratic Republic of Congo, South Sudan and Burundi, also face protracted civil wars with active rebel groups that have resulted in tens of thousands of deaths and millions of dollars in infrastructure losses.

All of this violence is hurting the investment climate (Costalli et al., 2017). This violence weaken and delay energy security (Ipek, 2017a), reduce or even eliminate energy investments (Bove et al., 2017 ; Steffen, 2018). They also have an impact on the financing of renewable energy (Rodríguez et al., 2015). Countries facing armed conflict will increase military spending (Sokhatskyi, 2020) and reduce their spending on the deployment of renewable energy sources. This will lead to a decrease in renewable energy consumption and an increase in fossil fuel consumption, thus penalizing the energy transition.

In this context, our article is motivated primarily by the climate emergency facing the world and the multiple challenges it poses. First, the energy transition is essential in the fight against climate change. By reducing greenhouse gas emissions from the production and consumption of renewable energy, we can help limit the devastating effects of global warming. Second, the energy transition creates opportunities for new markets and industries related to clean energy. This can stimulate economic growth and create jobs in these sectors. In addition, the energy transition through renewable energy choice is closely linked to many other sustainable development goals, including poverty reduction, access to clean and affordable energy, and the protection of the environment. Finally, research on energy transition through renewable energy choice will provide critical information to guide public policy and government decisions on energy and the environment. For all of these reasons, this article will focus on armed conflict as one of the challenges facing the energy transition in sub-Saharan Africa. There are several reasons for choosing sub-Saharan Africa as our field of study. First, Sub-Saharan Africa has a history of armed conflict and political instability in many countries, which unfortunately continues to this day. In 2017, the region recorded a quarter of the world's conflicts (95 out of 385) according to ACLED, making it the most violent region in the world. These conflicts have a profound impact on the region's energy systems. Second, Sub-Saharan Africa is rich in energy resources, particularly hydrocarbons and renewables. It is incomprehensible, however, that this region is still the least advanced in the use of renewable energy. Armed conflicts can have a major impact on the exploitation of these resources. In addition, many countries in the region, notably Senegal, Kenya, Burkina Faso, and many others, are in the process of developing their energy infrastructure. Conflict can disrupt these projects and have long-term consequences for the region's renewable energy choice. Conflicts in Sub-Saharan Africa can also have spillover effects beyond national borders. This can affect energy relations between countries in the region and require greater cooperation among these states. Finally, populations in sub-Saharan Africa are often among the most vulnerable to the effects of armed conflict. Understanding how these conflicts affect access to clean energy and the livelihoods of local communities is critical to a successful energy transition. For these reasons, our article examines the impact of armed conflict on the renewable energy consumption in sub-Saharan Africa.

Our paper therefore analyzes the economic impact of armed conflict on renewable energy consumption in Sub-Saharan Africa over the period 2000-2020. We make three main contributions to the economic literature. First, to the best of our knowledge, our paper is the first to analyze the impact of armed conflict on renewable energy consumption in sub-Saharan Africa. Second, this study takes into account the non-random distribution of armed conflicts in Sub-Saharan Africa and therefore uses spatial regression to analyze the spillover effect of these armed conflicts on the energy transition. In addition to considering spillovers, this article also uses a dynamic spatial model. This model captures the dynamic effects of armed conflict and shows the direct and indirect effects that armed conflict can have on renewable energy consumption in sub-Saharan Africa. Finally, the findings and recommendations of this study will help inform public decisions about the use of renewable energy and the fight against armed conflict in this hard-hit region.

To estimate the impact of the armed conflict on renewable energy consumption, we use spatial econometrics to take into account the spatial correlation due to the armed conflict (Cheng et al., 2018). The spatial regression of the Durbin error model is our main model. This method takes into account the spatial interactions between the countries in our sample in a linear regression context. It models how observations of one spatial unit (here the country) can be influenced by observations of neighboring spatial units. It thus avoids a strong bias(due to spillover effects) that can be present in standard econometric methods. We also use the dynamic version of the same model to estimate the dynamic effects of armed conflict. This dynamic model models how armed conflict and the energy transition process evolve over time, taking into account spatial interactions. Therefore, it considers both temporal and spatial dimensions and provides consistent and unbiased results (Elhorst, 2010). Using a sample of 46 countries over the period 2000-2020, we show in this article that armed conflicts have a negative and significant impact on the energy transition in Sub-Saharan Africa by negatively affecting renewable energy consumption. Our results are robust to several robustness tests. First, we use two alternative specifications. first, we change our dependent variable by using fossil fuel consumption instead of renewable energy consumption. The intuition is that in times of crisis, fossil fuel consumption would increase at the expense of renewable energy consumption, thus undermining the energy transition. Our results show that armed conflicts have a positive and significant effect on fossil fuel consumption. Second, we change our variable of interest by using the ratio of the number of deaths to the total population. We use two alternative methods : spatial autoregressive regression and spatial error model regression. The results remain the same, showing that armed conflict has a negative impact on energy transition. In terms of heterogeneity, we consider the effect of armed conflict in the Sahel and the rest of the countries in our sample. Moreover, according to the UCDP-PRIO database, there are four types of armed conflict [1]. We divide them into two categories, looking at the impact of terrorism (characterized by violence within the state) and the impact of other conflicts (extra-systemic, interstate and intrastate with support from other countries). Unlike the other conflicts listed, which are less widespread or even virtually non-existent, terrorism has taken hold in this region, causing many deaths and infrastructure losses. The results therefore show that the impact of terrorism is greater than that of other types of conflict.

Our article is organized as follows. Section 2 presents a literature review on the determinants of energy transition and the effects of armed conflict. Section 3 presents the data we use and the methodology we employ. Section 4 presents the empirical results of our study. Section 5 discusses the empirical implications. We conduct robustness tests in Section 6 and conclude in Section 7 with a presentation of our heterogeneity results.

2 Litterature review

In this section, we show the determinants of Renewable Energy and the impact of armed conflicts.

2.1 Renewable Energy

Energy Transition is a process that aims to move away from dependence on fossil fuels towards purely renewable, environmentally friendly energy consumption. Many recent studies have highlighted the multiple determinants of the energy transition. While some authors focus on microeconomic studies(Zhu et al., 2022 ; Baker et al., 2014), other authors have focused on macroeconomic studies (W. Przychodzen et J. Przychodzen, 2020 ; Popescu et al., 2018). The determinants of renewable energy are diverse but interrelated, ranging from socioeconomic and technological characteristics to political and country-specific factors(Bourcet, 2020).

Socio-economic characteristics include income, CO2 emissions, and energy demand. The first determinant, which has long been mentioned in the literature, is the economic factor of income (generally measured by GDP per capita). Indeed, the authors show that an increase

1. Uppsala Conflict Data Program

in income could lead to an increase in energy consumption, including renewable energy(Omri et Nguyen, 2014). Aguirre et Ibikunle (2014) show that income could boost the energy transition by increasing the financing of renewable energy projects. Sub-Saharan Africa, our area of study, is no exception. Silva et al., 2018 show over the period 1990-2014 that income measured by GDP per capita favors the energy transition by increasing renewable energy production in 17 sub-Saharan African countries. The second determinant is CO2 emissions. Several authors have shown that CO2 emissions encourage the use of renewable energy(Sadorsky, 2009). Causality is also inverse. Marques et al. (2010) show over the period 1990-2006 that an increase in CO2 emissions leads to a decrease in the use of renewable energy in a panel of European countries. In Africa, studies have also supported the hypothesis that CO2 emissions are a determining factor in the energy transition(Wiredu et al., 2023). Energy demand is the third socio-economic determinant (Silva et al., 2018). It is characterized by a country's population or population growth rate. Several authors have shown that population is negatively associated with the use of renewable energy (Aguirre et Ibikunle, 2014). Pfeiffer et Mulder (2013) shows that population growth delays the spread of non-hydro renewables in a study of 108 countries from 1980-2010.

In addition to socio-economic factors, political factors can have an impact on the renewable energy (Kilinc-Ata, 2016 ; Azam et al., 2021). Carley (2009) shows that the quality of political institutions affects the use of renewable energy over the period 1998-2006. The same is true for a panel of 22 emerging economies over the period 1990-2010, Wu et Broadstock (2015) show that better institutional quality is associated with higher renewable energy consumption. Numerous studies have also confirmed this hypothesis in sub-Saharan Africa (Bishoge et al., 2020).

Many factors are specific to a particular country. First, there's human capital. This factor influences renewable energy structure through innovation(Kato et al., 2015). In a study based on panel data for the period 2000 to 2019, Nawaz et Rahman (2023) show that human capital is positively associated with increased renewable energy consumption in 31 Sub-Saharan African countries. In a context outside Sub-Saharan Africa, Alvarado et al. (2021) show that human capital is a key factor in the energy transition, driving down non-renewable energy consumption in 27 OECD countries over the period 1980-2015. Industrialization also plays an important role in the energy transition (Jianchao et al., 2021). In Sub-Saharan Africa, Nyiwul (2017) show that industrialization has a significant impact on renewable energy consumption in a study of 27 countries over the period 1980-2011.

Other factors, such as foreign direct investment (Caetano et al., 2022 ; Appiah-Otoo et al., 2023), Trade openess (Murshed, 2020 ; Zhang et al., 2021 ; Opeyemi et al., 2019), urbanization (Baye et al., 2021 ; Mrabet et al., 2019) and abundance of natural resources (Ahmadov et Van Der Borg, 2019 ; Han et al., 2023) determine renewable energy structure in the world in general and in Sub-Saharan Africa in particular.

One of the challenges facing the Sub-Saharan Africa region in recent years has been armed conflict. These conflicts undermine renewable energy consumption through renewable energy financing (Yang et al., 2022 ; Pereira et al., 2022). In a panel study covering the period 2010-2020, Muoneke et al. (2023) show the dynamic effects of armed conflict on renewable energy financing. The authors find that armed conflict weakens the energy transition by reducing financing for renewable energy. However, to the best of our knowledge, there are no studies on the impact of armed conflicts in Sub-Saharan Africa on renewable energy consumption. In this context, we will focus on armed conflict as the main obstacle to energy transition in sub-Saharan Africa.

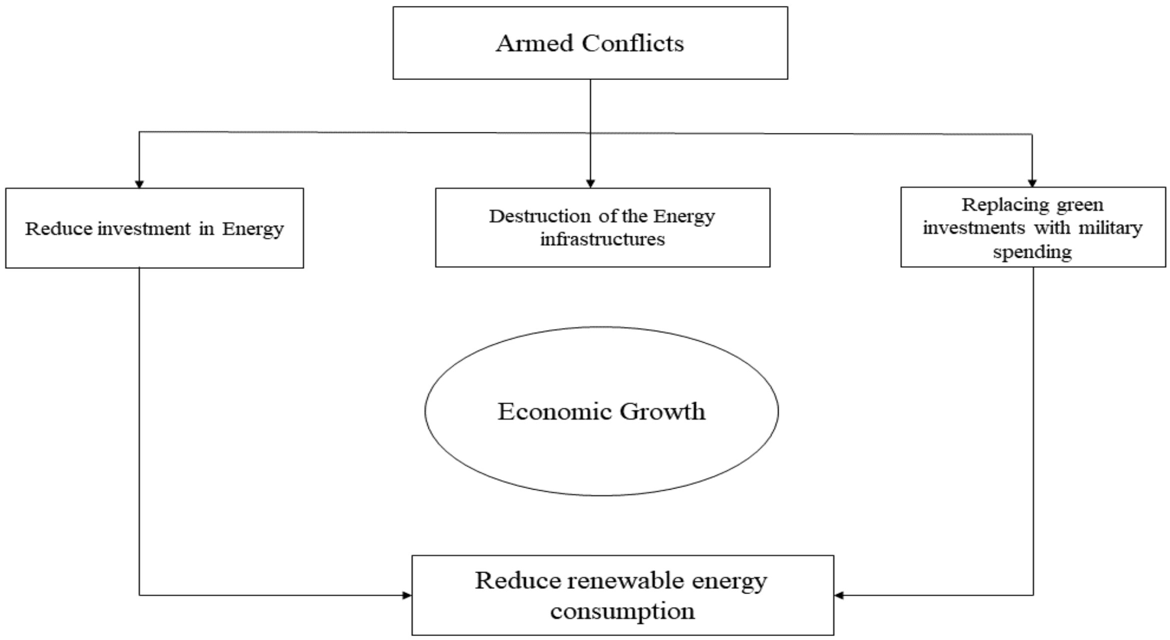
2.2 Armed Conflicts

The economic literature shows that armed conflict has multiple consequences.

Theoretical studies have shown that armed conflicts can have a negative impact on a country's economic development. The proposed channels are technology transfer (Takarada, 2005), international trade and foreign direct investment (Kuang et al., 2017), destroying many infrastructures and relations between countries (Costalli et al., 2017 ; Ruiz Estrada et al., 2018).

Empirically, studies have shown that armed conflict is initially a source of great uncertainty and disruption to society (Bove et al., 2017). Armed conflicts have a negative impact on the health of children and women in particular(Bendavid et al., 2021), have an impact on the mobilization of tax revenues(Gupta et al., 2007). These various effects are reflected in the economic development of the countries. These countries will depend on the finan-

Figure 1 – Transmission Channels



Source : Author

cing of renewable energies (Yang et al., 2022). On a panel of 43 African countries over the period from 1950 to 2010, Poirier (2012) shows that armed conflicts lead to a decline in school enrollment and that military spending increases in times of conflict. It is therefore expected that there would be a substitution between military spending and spending on renewable energy. By affecting economic development, armed conflict will play an important role in the deployment of renewable energy through industrialization (Tang, 2020) and the availability of funds to invest in renewable energy research and deployment (Chen et Lin, 2020 ; Gabteni et Bami, 2018). We can also expect these conflicts to have a direct impact by destroying a lot of infrastructure, including energy infrastructure (Murdoch et Sandler, 2004). Using the synthetic control method on a panel of 20 countries, Costalli et al. (2017) show that armed conflict can also affect a country's business climate and discourage investment. Steffen (2018) shows empirically for the period from 2010 to 2015 that armed conflicts reduce investment in the energy sector and can therefore lead to energy insecurity(Ipek, 2017b).

In light of this literature, we can see that armed conflicts can affect the energy transition through the consumption of renewable energy through several possible channels, including the destruction of energy infrastructure, the substitution of renewable energy investment expenditures for current military expenditures, the economic development of countries and the business climate, thus penalizing investment in the energy sector. These channels are summarized in the figure 1.
We will describe the empirical method we use to demonstrate the impact of armed conflict on renewable energy consumption in the rest of our study.

3 Methodology and data

In this section, we first present our theoretical framework, then we present our econometric methodology, and finally, we present the data that we use.

3.1 Theoretical and econometric framework

Sub-Saharan Africa faces a major challenge in achieving a sustainable energy transition and promoting economic development. Unfortunately, armed conflict in many parts of the continent is seriously hampering these efforts.

To examine the impact of these conflicts on renewable energy consumption, this study adopts a multivariate framework that identifies armed conflict as one of the many determinants of energy transitions [2].

To analyze the dynamic and spatial effects, we add a dynamic spatial model with fixed effects, which allows us to account for the multiple shocks that can arise from armed conflict and affect renewable energy consumption in time and space. The result is the dynamic spatial fixed effects model below :

$$RENC_{it}=\alpha_i + \tau RENC_{it-1} + \rho \sum W_{ij} RENC_{it} + \beta_0 Conflict_{it} + \beta_1 \sum W_{ij} Conflict_{it} + \beta_2 X_{it}$$

2. Following(K. Dong et al., 2018 ; Balsalobre-Lorente et al., 2018). We have so the following model :

$$RENC_{it} = f(Conflict_{it}, X_{it})$$

$RENC_{it}, X_{it}$ represent respectively renewable energy consumption and the set of control variables included in our model for country i in year t

$+\beta_3 \sum W_{ij} X_{it} \ + \pi_{it}$

Where

$$\pi_{it}= \sigma \sum W_{ij} \pi_{it} + \epsilon_{it}$$

In this model, we obtain three spatial impact characteristics : endogenous spatial impact ($\sum \mathrm{W}_{ij} RENC_{it}$), The exogenous spatial effect of all the control variables we include in our model. ($\sum \mathrm{W}_{ij} X_{it}$) and residual spatial impact($\sum \mathrm{W}_{ij} \pi_{it}$). We have also α_i which corresponds to the fixed effects parameter we include in our model. As for τ, β et π, are the coefficients of the three spatial effects in spatial econometrics. W_{ij} is a spatial weight of a spatial weight matrix W (row standardized contiguity matrix), which has been widely used in the literature (LeSage et Pace, 2009) and so we used it.

To estimate the parameters of these three types of characteristics, we need three types of models (Manski, 1993) spatial econometrics (because it is not possible to estimate all three of them in the same model). Thus, there are three types of spatial econometric models for panel data. We have the autoregressive spatial model, also known as SAR, which takes into account the first spatial impact characteristic (endogenous spatial impact with $\beta = \sigma = 0$), the spatial error model(SEM) that accounts for spatial interaction disruption($\beta = \tau = 0$) and Durbin spatial error model (SDM) containing both endogenous and exogenous spatial interaction ($\sigma = 0$) and thus account for the potential bias associated with endogeneity. These three models give static (non-dynamic) results. However, dynamic results can be obtained by including temporal and spatial lag components in the model. In this model, we have chosen to use Durbin's spatial error model because it provides us with consistent and unbiased results, taking into account endogeneity, while strengthening the explanatory power of our explanatory variables(Elhorst, 2010). Following Elhorst (2010), We use a likelihood ratio test to show that the choice of this model is not based on intuition alone, but that it is preferable to the other two SAR and SEM models. Our final spatial econometric model, based on the Durbin error model, is given by the equation below :

$$RENC_{it}=\alpha_i + \tau RENC_{it-1} \ +\rho \sum W_{ij} RENC_{it} \ + \ \beta_0 Conflict_{it} + \beta_1 \sum W_{ij} Conflict_{it} \ +\beta_2 X_{it}$$
$$+\beta_3 \sum W_{ij} X_{it} \ + \ \epsilon_{it}$$

Where X represents the urbanization rate, per capita income, and natural resource rents, which are our control variables.
Estimating our model using ordinary least squares would produce biased results due to potential endogeneity bias, which could be due to omitted variables or simultaneity bias here. To this end, to estimate our dynamic and non-dynamic spatial model based on the Durbin model, we apply the quasi-maximum likelihood method, as also used by Yu et al. (2008).

3.2 Methods

Three steps are essential when we want to run regressions based on spatial econometric models. First, we need to verify that there is indeed spatial autocorrelation in the panel data we are using. To do this, we need to run the Moran test and check that this correlation does indeed exist. Then we need to see which of the three spatial econometric models listed above is the most appropriate. This requires a likelihood ratio test. Finally, having chosen the appropriate model, we can run the regressions and see the decomposed effects (direct and indirect). In this section we follow these steps, first presenting Moran's test, then the model selection, and finally a presentation of the structure of the direct and indirect effects that the dynamic method gives us as an advantage.

3.2.1 Moran's test

Developed by Moran (1950), It allows us to check the spatial autocorrelation of armed conflicts in our model. The equation is given by :

$$\text{Moran's I}= \frac{\sum_i \sum_j W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})}$$
$$\text{with } \bar{X}= \frac{1}{N}\sum_{i=1}^{N} X_i.$$

X_i is just the first difference of our variable of interest "*Conflict* " dans le pays "i". N is the total number of countries in our sample, i.e. 46. Thanks to this formula, we can derive "Z", which represents the power of the spatial autocorrelation. Its formula is given by the following equation :

$$Z=\frac{I - E(I)}{SD(I)}$$

where

E(I) and SD(I) are the mean and standard deviation, respectively, of the Moran test. To check for spatial autocorrelation, we look at the value of Z. [3]

3.2.2 Model selection

We initially decided to use Durbin's spatial model. However, we need to verify that it is the most appropriate of the three models (SDM, SEM, and SAR) for our data before proceeding with the econometric regressions. To do this, we perform likelihood ratio tests as suggested by Elhorst (2010) and also used by (Feng et Wang, 2020 ; Ren et al., 2021). [4].

3.2.3 Composition effect

In our model, spillovers and spatial autocorrelation mean that the coefficients of our explanatory variables do not give us the exact marginal effects (You et Lv, 2018). To do this, we use Durbin's dynamic spatial model to obtain estimates of the coefficients of our explanatory variables, which are decomposed into two effects : short-term effects and long-term effects. These two main effects can be decomposed into four sub-effects : direct and indirect short-term effects, and direct and indirect long-term effects. The equations for these different estimates are presented below :

$[(I-\rho W)^{-1} * (\beta_k I + \lambda_k W)]^{\bar{d}}$ represents short-run direct effects, $[(I-\rho W)^{-1} * (\beta_k I + \lambda_k W)]^{rs\bar{u}m}$ represents short-run indirect effects, $[((1-\tau)I-\rho W)^{-1} * (\beta_k I + \lambda_k W)]^{\bar{d}}$ represents long-run direct effects and finally $[((1-\tau)I-\rho W)^{-1} * (\beta_k I + \lambda_k W)]^{rs\bar{u}m}$ represents long-run indirect effects.

I_n is an identity matrix of size n. $(I-\rho W)^{-1})$ is the spatial matrix multiplier we've built, $\bar{d}$ simply represents the coefficient averaged over the diagonal elements of the matrix we have constructed, $rs\bar{u}m$ is simply the sum of the means of all elements not included in the diagonal. The short-run and long-run effects are the marginal effects in the dynamic spatial model.

3. A larger value of Z is associated with the existence of spatial autocorrelation.

4. On the other hand, having performed these tests and determined which of the models is the most appropriate, we now need to determine which model to choose between the fixed effects model and the random effects model. To do this, we use the Hausman test, as is often done in the economics literature

3.3 Data

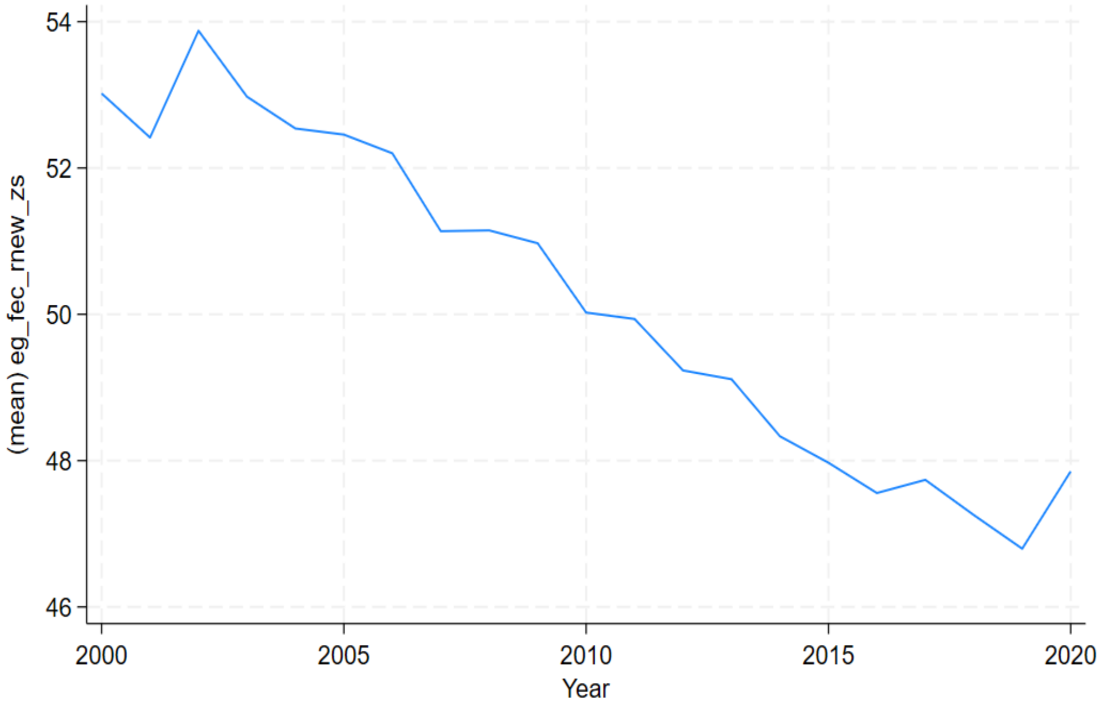
To analyze the impact of armed conflict on renewable energy, we use a well-cylindrical data panel of 46 countries over the period 2000-2020.

Our dependent variable characterizing renewable energy transition is represented here by renewable energy consumption (wind, hydro, solar, tidal, geothermal, biomass). According to IEA, Energy transition refers to the shift from an energy system based primarily on fossil fuels to one characterized by greater use of renewable, lower-carbon energy sources. Renewable energy sources, such as solar, wind, hydro, and biomass, generally produce less or no greenhouse gases when used to generate electricity or heat. Increasing the share of renewable energy in total energy consumption helps to reduce emissions of CO2 and other air pollutants associated with fossil fuels. The choice of this variable is mainly motivated by the fact that an energy transition is based on the exclusive consumption of renewable energy. Many authors (F. Dong et al., 2022 ; Dietzenbacher et al., 2020) have also used this variable to characterize the energy transition in their work. Graph 2 shows a decline in consumption in recent years. The data for this variable comes from the World Bank website.

Our variable of interest here is a binary variable coded 1 if the country has experienced at least one armed conflict and 0 otherwise. The UCDP-PRIO defines an armed conflict as an attack or conflict that results in at least 25 deaths in a given calendar year (Davies et al., 2023). We consider all types of armed conflict that exist in the database. Conflict trends in the countries in our sample are shown in Figure 3. The data for this variable come from the UCDP-PRIO website.

We also use three control variables, chosen according to data availability. The first is GDP per capita, which represents income per capita. This is one of the most important determinants of energy transition. Countries with high GDP per capita generally have more financial resources to invest in renewable energy technologies and infrastructure. This includes building wind and solar farms, developing modern electricity grids, and improving energy efficiency. Armed conflicts tend to drive populations into urban centers. This can have two effects. The first is mainly due to the fact that it could be an opportunity to take advantage of the concentration of energy to implement renewable energy policies. However, it could also have a negative effect on the energy transition, as the concentration in urban centers

Figure 2 – Renewable Energy Consumption Trend



Source : Author

could prevent governments from implementing policies by redirecting their policies towards the needs of the moment (food policies, housing policies...). For these reasons, we include the urbanization rate as a second control variable. Natural resources also play a crucial role in the energy transition. They can be used to finance renewable energy deployment projects (Huang, 2022) or discourage investment in renewable energy due to dependence on natural resources. Within this framework, we therefore include a third control variable representing rents from natural resources. The data for these different control variables are taken from the World Bank website. [5]. Table 1 presents the descriptive statistics for these different variables.

5. https ://databank.worldbank.org/source/world-development-indicators

FIGURE 3 – Armed Conflicts Trend

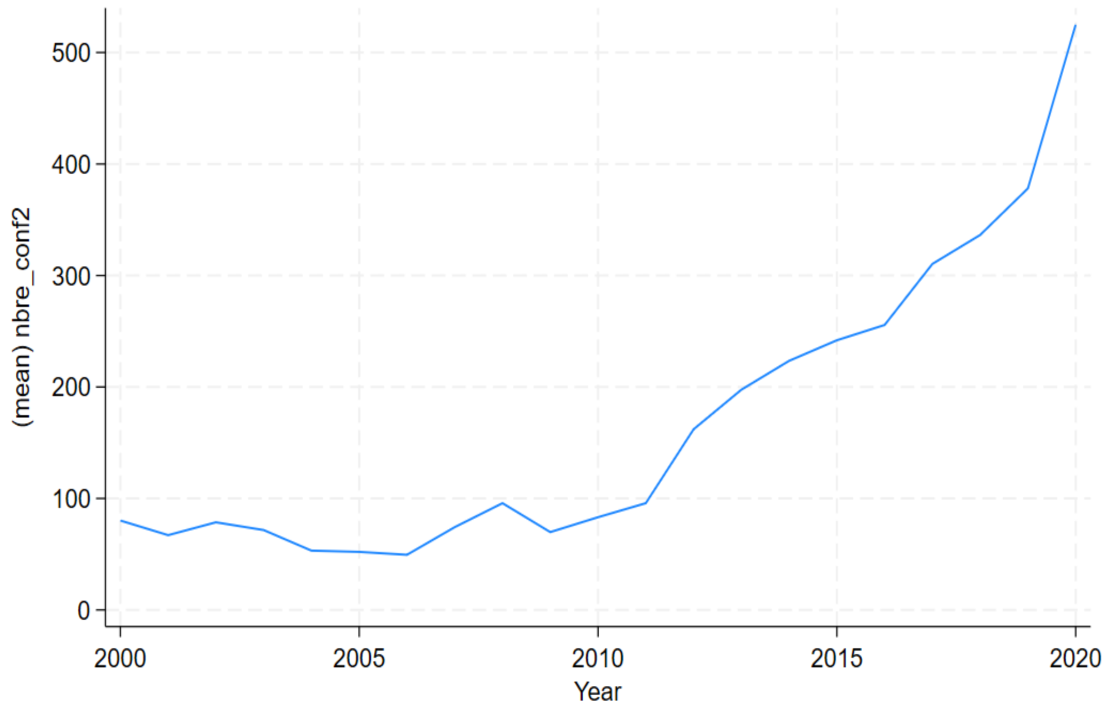


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TABLE 1 – Statistiques Descriptives

	mean	min	max	sd
Renewable Energy consumption(log)	3.331207	-4.60517	4.588431	1.595832
Conflict	.2287785	0	1	.4202639
Urbanization(%)	48.67593	8.246	100	20.16154
Natural ressources(%GDP in log)	1.546019	-6.049184	4.374888	1.784248
GDP Per capita (log)	8.00672	0	11.42393	1.979147
Observations	966	966	966	966

4 Empirical results

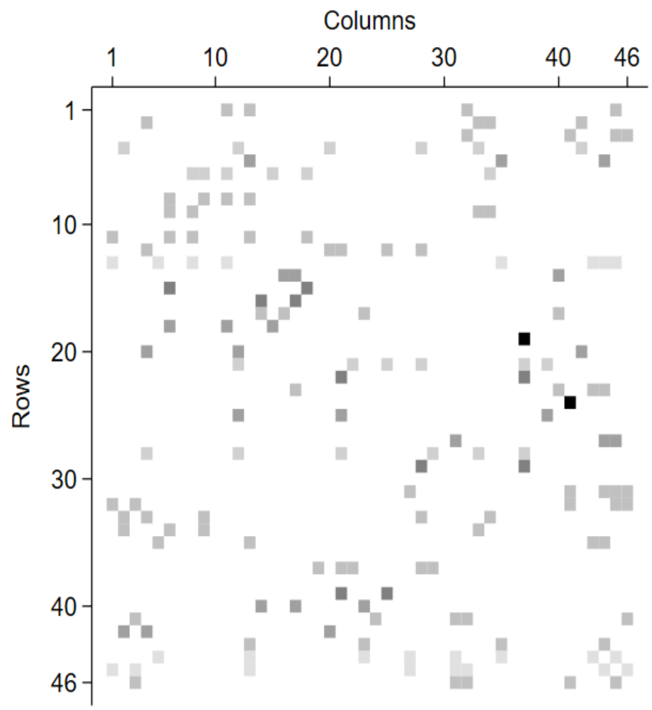
In this section, we first discuss the choice of the proximity matrix, then show the existence of spatial correlation of armed conflicts between different countries and the results of model selection, and finally conclude with the results of our various regressions.

4.1 Weighting matrix

Specifying our model involves choosing a weighting matrix. The weighting matrix is a crucial element used to model spatial dependencies between observations. This weighting matrix captures the spatial relationships between different geographical units, and here between countries in sub-Saharan Africa. The weighting matrix assigns weights to pairs of observations according to their spatial proximity. There are several ways to define this matrix in spatial econometrics, and the choice depends on the specific context of the study. In our case of armed conflict, we construct a weighting matrix based on inverse distance to capture the effect of proximity based on the distance of the countries in our sample. This spatial weighting matrix is row-standardized. It is denoted as W_{ij} and thus represents the inverse of the distance between countries "i" and "j".

This approach generally assumes that closer spatial units have a stronger spatial relationship, i.e. observations located close to each other will have a greater impact on each other, which is well in line with the idea that armed conflict in one country "i" can spill over into its neighbor "j".

FIGURE 4 – Matrix distribution



Source : Author

4.2 Spatial autocorrelation test

Before running our regressions, we first look at whether there is any spatial correlation between the armed conflicts in our sample of countries. As we can see in Figure 6, The countries of the Sahel belt and some Central African countries are more prone to armed conflict (average 2000-2020). We also note that these countries are interconnected (bordering). This shows the spatial correlation of our armed conflicts. In fact, if a country has recorded at least one armed conflict, it could be that the neighboring country has also been affected by at least one armed conflict in the same year.

Then, to confirm our intuition about the spatial correlation that may exist, we perform Moran's test. The results are shown in the table below 2 :

The larger the Z value, and the more significant at least the 10% the greater the spatial autocorrelation of armed conflicts in our sample. The results presented in Table 2 show us that there is a correlation and that traditional regression methods would give us biased estimates due to spillover effects. Given this information, we need to use a spatial econometric

Table 2 – Moran's test results

Variables	Z	P-Value	Variables	Z	P-value
2000	2.243**	0.012	2012	-0.126	0.450
2001	1.875**	0.03	2013	-0.083	0.467
2002	1.569*	0.058	2014	0.551	0.291
2003	0.464	0.321	2015	2.857***	0.002
2004	-0.616	0.269	2016	2.296**	0.011
2005	2.891***	0.002	2017	2.461***	0.007
2006	3.545***	0.000	2018	1.888**	0.029
2007	1.684**	0.046	2019	2.675***	0.004
2008	2.891***	0.002	2020	3.686***	0.000
2009	-0.019	0.492	2010	1.347*	0.089
2011	0.457	0.324			

method to estimate the effect of armed conflict on renewable energy consumption.
In the next section, we'll see which spatial econometric method we should choose to analyze the effects of armed conflict.

4.3 Model selection

In this section, we present the results of our model selection. First, we perform a likelihood ratio test to see which of the three spatial econometric models is preferred for our estimations. First, we compare the SDM model to the SEM model. The null hypothesis implies that the SDM model is preferable to the SEM model. The result of the likelihood ratio test gives us a value of 2.47 with a p-value of 0.6492. This means that the null hypothesis cannot be rejected and that the SDM model is preferable to the SEM model. On the other hand, we now perform another test comparing the SDM model with the SAR model. We find a Chi2 value of 2.63 with a P-value of 0.6221. So we can't reject and again we find that the SDM model is preferable to the SAR model. In short, the SDM model is more appropriate for our purposes than the other types (SAR and SEM). Having chosen the SDM model, we perform the Hausman test to see which model is preferable between the SDM fixed effects model and the random effects model. The test result gives us a value of 208.32 with a p-value of 0.000. This means that the fixed effects model is preferable to the random effects model. The results are shown in Table 16.

4.4 Spatial regression models

Once the appropriate model is chosen, we can empirically test the effect of armed conflict on energy transition. We therefore use both the SDM fixed effects model and the SDM dynamic fixed effects model. The results are shown in Table 3. As we can see, the fact that a country is affected by at least one armed conflict in a given year reduces its renewable energy consumption according to both types of models (dynamic and non-dynamic). More specifically, the fact that a country is affected by at least one armed conflict reduces its renewable energy consumption by 30.97% [6] according to the dynamic model.
Several explanations can be given.

One explanation is that one of the most immediate impacts of armed conflict on the energy transition in sub-Saharan Africa is the destruction of existing energy infrastructure. The University of Cape Town's Energy Research Institute explains in its recent 2022 report that armed conflict has led to the destruction of almost 40% energy infrastructure in certain affected regions. These include power plants, transmission lines, and solar-based distribution networks. These conflicts undermine the efforts of various governments and penalize the energy transition.

Another explanation is that armed conflict creates a climate of economic uncertainty that deters foreign investors from engaging in the energy sector in sub-Saharan Africa. According to the World Bank, FDI in the energy sector in Sub-Saharan Africa has fallen by 30% in conflict-affected regions in recent years. International companies are reluctant to commit to energy projects in unstable areas where sporadic violence can disrupt or jeopardize operations. Energy companies operating in conflict-affected areas often have to devote a significant portion of their resources to security. This includes hiring private security guards, installing advanced surveillance systems, and other measures to protect facilities and personnel. These additional costs reduce the profitability of projects and can deter potential investors.

6. Calculation using exponential

Table 3 – SDM and Dynamic SDM : Renewable Energy Consumption

VARIABLES	SDM Main	SDM std.error	Dynamic SDM Main	Dynamic SDM std.error
Conflict	-0.162***	(0.0356)	-0.172***	(0.0355)
urbanization	0.00501	(0.00553)	0.0102*	(0.0057)
Rents	0.0262	(0.0206)	0.00826	(0.0203)
GDP-Per-Capita	0.00343*	(0.0269)	0.00824**	(0.0289)
L.RENC [7]			-0.323**	(0.135)
Wx				
WConflict	-0.118*	(0.0654)	-0.136**	(0.0653)
WUrbanisation	0.0191*	(0.00993)	0.0165	(0.0105)
WRenst	0.128**	(0.0533)	0.135***	(0.0525)
WGDP-Per-Capita	0.0474	(0.0293)	0.0510	(0.0314)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Finally, in times of armed conflict, governments are under considerable pressure to ensure national security and defense. This often involves massive investments in the armed forces, armaments, maintenance of military equipment, and law enforcement operations. These expenditures absorb a significant portion of the national budget, leaving fewer resources for other sectors, including renewable energy. These conflicts are often accompanied by immediate security, infrastructure and reconstruction needs. Governments may be encouraged to allocate resources to these short-term priorities rather than to longer-term investments in energy transition projects that take time to deliver tangible benefits. We are therefore witnessing a substitution or crowding out effect of renewable energy investments for military spending.

In the next section, we discuss the spatial and disaggregated effects of armed conflict on energy transitions.

5 Discussion

In this section, we discuss the spillover effects found in the results above as well as the decomposition effects.

5.1 Spatial spillover effects in Subsaharan Africa

The spatial lag of our variable of interest (WConflict) is negative and significant. This confirms the results of our Moran spatial correlation test and confirms that the distribution of armed conflicts in the Sub-Saharan African zone is not random, but can be influenced by conflicts in neighbouring countries. Based on the results of the dynamic model, we can see that the fact that a neighbouring country has suffered at least one armed conflict, through a contagion effect, immediately leads to a drop in 32.11% renewable energy consumption in the local country. In addition to the reasons mentioned above, there are several other possible explanations. First, renewable energy supply agreements between countries can be affected by unstable conflict conditions, leading to delays, cancellations, or reductions in planned deliveries. When renewable energy supplies are disrupted as a result of a conflict (e.g., Côte d'Ivoire and Burkina Faso), the neighbouring country may be forced to rely more heavily on fossil fuels to meet its energy needs. This can lead to increased consumption of fossil fuels at the expense of renewable energy. Second, in times of conflict, there is massive displacement of people from one country to another. This in turn increases global energy demand. However, in times of conflict, as mentioned above, needs are prioritized and, unfortunately, efforts to deploy renewable energy diminish. As a result, fossil fuel consumption increases to meet the demand created by mass displacement. Finally, armed conflict creates diplomatic and political tensions between neighbouring countries, which can complicate cooperation on renewable energy deployment.

5.2 Directs and indirect effects

The presence of spillover effects and thus spatial correlation, as shown above, means that the effects of armed conflict are not limited to the local country, but can directly or indirectly affect the neighbouring country(You et Lv, 2018). With this in mind, this section

Table 4 – Short-Run Effects

VARIABLES	Main	std.error
Short-run direct effects		
Conflict	-0.2035107***	0.0364669
urbanization	-0.0128318**	0.0051534
Rents	-0.0308125	0.0201383
GDP-Per-Capita	0.0036353**	0.0106759
Short-run indirect		
Conflict	-0.0675975	0.0600607
urbanization	0.0020648	0.006294
Rents	0.0309429	0.0355237
GDP-Per-Capita	0.0114771	.0252454
Short-run Total		
Conflict	-0.2711082***	0.0736099
urbanization	-0.010767**	0.0045692
Rents	0.0001304	0.0362992
GDP-Per-Capita	0.0151123**	0.0265214
Number of ID	46	46

*** p<0.01, ** p<0.05, * p<0.1

presents the direct and indirect effects of these conflicts. Direct effects are those caused by armed conflict in the local country, while indirect effects are those caused by armed conflict in neighbouring countries. We also include the total effects (direct and indirect), which are the gross effects in the short and long run. The results based on the dynamic model are presented in the tables below 4 and 5. As we can see, the coefficient of our variable of interest is different from the main results. In our main model, we obtain a decrease of 30%, But if we break this down, we find that the direct effect is 30,01%(-0.2035) in the short term (-0.2035). This is mainly due to the feedback effect. The latter is caused by the influences transferred to the local country by its neighbors(LeSage et Pace, 2009). The feedback effect is therefore calculated as the difference between these two coefficients. This results in a feedback effect of 0.96%. The short- and long-run direct coefficients of our "conflict" variable are negative and significant at 1%. This means that the fact that the local country experienced at least one armed conflict in a given year reduces its consumption of renewable energy. However, the indirect short- and long-term effects are insignificant. Thus, the explanation here is that the effect of armed conflict on renewable energy consumption in the local country is much

Table 5 – Long-Run Effects

VARIABLES	Main	std.error
Long-run direct effects		
Conflict	-0.2021539***	0.0365905
urbanization	-0.0130383**	0.0054071
Rents	-0.0325067	0.0207808
GDP-Per-Capita	0.0031375**	.0109348
Long-run indirect		
Conflict	-0.0286847	0.0519841
urbanization	0.0037675	0.006111
Rents	0.0319628	0.0321968
GDP-Per-Capita	0.0095789	.0224621
Long-run Total		
Conflict	-0.2308386***	0.0613409
urbanization	-0.0092709**	0.0038235
Rents	-0.0005439	0.03043
GDP-Per-Capita	0.0127164**	0.022227
Number of ID	46	46

*** p<0.01, ** p<0.05, * p<0.1

larger than the spillover effects caused by armed conflict in neighbouring countries. In the next section, we test the validity of our results.

6 Robustness checks

Our main results show that armed conflicts penalize the energy transition by reducing the consumption of renewable energy. In this section, we test the robustness of our results using two alternative specifications, two alternative methods, and additional control variables.

Table 6 – SDM and Dynamic SDM : Fossil Fuel Consumption

VARIABLES	SDM Main	SDM std.error	Dynamic SDM Main	Dynamic SDM std.error
Conflict	0.1279274***	(0.0435942)	0.0901726**	(0.0458859)
urbanization	0.0010919	(0.006778)	-0.01248**	(0.006351)
Rents	0.0508199	(0.0251409)	0.0389547	(.0254744)
GDP-Per-Capita	0.0012589	(0.0134084)	-0.0044966	(0.0135167)
L.FFC			0.157965**	(0.0793777)
Wx				
WConflict	0.0707522	(0.0803468)	-0.0616604	(0.0813159)
WUrbanization	0.0367926***	(0.0121935)	0.0194641**	(0.0087152)
WRents	0.1067242	(0.0656764)	0.116976**	(0.054281)
WGDP-Per-Capita	-0.1273801***	(0.0360517)	-0.1562259***	(0.0345077)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6.0.1 Alternative specifications

To show that armed conflict undermines the energy transition, we chose to use fossil fuel consumption instead of renewable energy consumption as the first alternative specification. As mentioned above, armed conflict can lead to the destruction of renewable energy infrastructure, reduced investment in renewable energy projects, and political instability. We therefore expect a decrease in renewable energy consumption. Our intuition here is that this decrease in renewable energy consumption will be offset by an increase in fossil fuel consumption to meet energy demand. Data from the World Bank website. The results are shown in the table 6. We can see that if a country has experienced at least one armed conflict, its fossil fuel consumption increases by 41.8% for the dynamic model against 40.25% for the non-dynamic model. As we can see, this is roughly equivalent to the reduction in renewable energy consumption. This confirms our intuition and shows that armed conflicts undermine the energy transition.

As a second alternative specification, we use the number of deaths caused by armed

Table 7 – SDM and Dynamic SDM : Deaths

VARIABLES	SDM Main	SDM std.error	Dynamic SDM Main	Dynamic SDM std.error
Death	-0.00453**	(0.00204828)	-0.0055999***	(0.0017105)
urbanization	-0.0118035***	(0.0039237)	-0.0119184***	(0.0044102)
Rents	-0.0287089	(0.0381853)	-0.0566687*	(0.0329979)
GDP-Per-Capita	0.0000489***	(0.0000102)	0.0000529***	(0.0000106)
L.RENC			-0.1544963**	(0.0767137)
Wx				
WDeath	0.0091525***	(0.0027941)	0.0082701***	(0.0028643)
WUrbanization	-0.0017023	(0.0030087)	-0.0017842	(0.0030293)
WRents	0.0831663**	(0.039891)	0.1062067***	(0.0370619)
WGDP-Per-Capita	-0.0000347***	(0.0360517)	-0.0000339***	(4.57e-06)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

conflict as a share of the total population. The idea here is to show that the increase in the number of deaths caused by armed conflict is associated with a decrease in the consumption of renewable energy. The data come from the ACLED website. The results are shown in the table 7. The results clearly show that armed conflicts have a negative and significant impact on renewable energy consumption, thus undermining the energy transition.

6.0.2 Alternative estimation methods

In this section, we use the other two estimation methods of spatial econometrics to demonstrate the robustness of our results. In addition to SDM regression, these are SAR regression and SEM regression, as mentioned above. Results are shown in tables 8 et 9. The results are the same, proving that armed conflicts undermine the energy transition by reducing the

Table 8 – SAR and Dynamic SAR : Renewable Energy Consumption

VARIABLES	SAR Main	SAR std.error	Dynamic SAR Main	Dynamic SAR std.error
Conflict	-0.1832189 ***	(0.0367528)	-0.1805947 ***	(0.0372555)
urbanization	-0.0112927***	(0.0036262)	0.0131862**	(0.0058785)
Rents	-0.0050746	(0.0203372)	-0.0384919*	(0.0212032)
GDP-Per-Capita	-0.0007863	(0.0109973)	0.0185555*	(0.0111918)
L.RENC			-0.4217317***	(0.1407184)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9 – SEM : Renewable Energy Consumption

VARIABLES	SEM Main	SEM std.error
Conflict	-0.1855409 ***	(0.037003)
urbanization	-0.0108103***	(0.0035106)
Rents	-0.0056489	(0.0201313)
GDP-Per-Capita	-0.0005281	(0.0109503)
Observations	966	966
Number of ID	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

consumption of renewable energy sources.

6.0.3 Additional control variables

In this last section, we add additional control variables to minimize the bias associated with the omitted variables and to check the robustness of our results.

First, we include a variable that captures the level of industrialization of the country. In addition to the high energy demand of these industries, we expect industrialization to be followed by the development of new, cleaner (renewable) energy sources. Indeed, industrialized countries are more likely to have access to the advanced technologies needed to produce and use renewable energy, which can make these energy sources more competitive with fossil fuels. It is in this context that we include this variable, measured by industrial value added as a percentage of GDP. It has also been used by several authors (Hao et al., 2016 ; Zhao et al., 2022).

We then add another variable that captures and measures human capital. Indeed, we must not minimize the effects of capital as a factor of innovation(Kato et al., 2015). For a successful energy transition, the workforce must be educated and trained to understand, implement, and maintain new technologies and infrastructure. This includes training workers in the renewable energy sector, as well as raising public awareness of energy issues. Therefore, we include this variable as (Zhao et al., 2022) in our study. It is measured by the gross secondary school enrollment rate.

Open trade can play a major role in the energy transition. In addition to generating innovation (Love et al., 2014), Countries with a high degree of trade openness benefit from other countries' experience and resources for innovation(Dahlander et Gann, 2010). It is in this context that we include this important control variable in our study. It is measured by the sum of imports and exports of goods and services as a percentage of GDP.

Finally, we add the size of the population, which affects consumption. The data for these variables are taken from the World Bank website. The results are shown in the table 10. When we add these different additional control variables, we get the same results. We come to the same conclusion : armed conflicts undermine energy transitions.

Table 10 – SDM and Dynamic SDM : Renewable Energy Consumption (Additional control)

VARIABLES	Dynamic SDM Main	Dynamic SDM SDM Main	Dynamic SDM Main	Dynamic SDM Main	Dynamic SDM Main
Conflict	-0.172***	-0.1713111***	-0.1706683***	-0.1706234***	-0.1711049***
urbanization	0.0102*	0.0100959*	0.0099694*	0.0098401*	0.0099463*
Rents	0.00826	0.007971	0.0080094	0.0069528	0.0068492
GDP-Per-Capita	0.00824**	0.0080076	0.0080087	0.0078341	0.0011101
Trade		0.0001581	0.0001846	0.0001648	0.0001634
Industry			0.0012065	0.0011387	0.0011101
Human_capital				-0.0011615**	-0.0011535**
Population					-1.52e-09
L.RENC	-0.323**	-0.3286589**	-0.3388573**	-0.3220677**	-0.3195829**
Wx					
WConflict	-0.136**	-0.1366299**	-0.1354597**	-0.1373167**	-0.1361063**
WUrbanization	0.0165	0.0157328	0.015334	0.0148774	0.0146729
WRents	0.135***	0.1384704***	0.1420128***	0.1465008***	0.1453245***
WGDP-Per-Capita	0.0510	0.0496832	0.0473333	0.0456347	0.046218
WTrade		0.0009238	0.0009666	0.000958	0.0009552
WIndustry			0.0029865	0.0027172	0.0027076
WHuman_capital				0.0013485	0.0013452
WPopulation					1.17e-09
Observations	920	920	920	920	920
Number of ID	46	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7 Heterogeneity analysis

In this section, we conduct two heterogeneity tests. In the first subsection, we look at the effect of different types of conflict. In the second subsection, we look at the effect of armed conflict in the Sahel zone, which has seen the most conflict in recent years(Welz, 2022).

7.1 The heterogeneity results of different conflicts

As mentioned above, we divide conflicts into two types. We, therefore, look at the impact of terrorism and the impact of other types of conflict interstate, intrastate and internationalized intrastate (voir https ://ucdp.uu.se/downloads/ucdpprio/ucdp-prio-acd-231.pdf). Terrorism is one of the challenges facing countries in sub-Saharan Africa. The impact of terrorism is greater than that of other types of conflict in that it leads to significant energy destruction and substitution effects. Given these effects, it undermines the efforts of governments to deploy renewable energy. The effects of terrorism are therefore expected to be higher than those of other types of conflict. The results are shown in the table 11.

As we can see, we get a negative and significant effect at 1% for terrorism, and no effects for other types of conflict in the table 14 in appendix.

7.2 The heterogeneity results in Sahel

In this section, we examine the impact of armed conflict on the energy transition in the Sahel zone. The idea is to see if the role of armed conflict is greater in this zone than in the rest of the sample. In doing so, we also capture the intensity of the conflict. According to the latest Amnesty International report, the Sahel is one of the regions of the world with the highest number of armed conflicts in recent years. So we split our sample in two and look at the effect in the countries [8] in the heart of the Sahel zone and the rest of our sample. The results based on the dynamic model are presented in 13. As we can see, the effect of armed conflict is much higher in the Sahel countries than in the rest of our sample, at 35.55% and 29.57%, respectively.

8. Burkina Faso,Mali,Niger

Table 11 – SDM and Dynamic SDM : Effect of terrorism

VARIABLES	SDM Main	SDM std.error	Dynamic SDM Main	Dynamic SDM std.error
Terrorism	-0.3310082***	(0.0543265)	-0.2663812***	(0.0536706)
urbanization	0.0029577	(0.0055104)	0.0086763	(0.0057873)
Rents	0.025953	(0.0203814)	0.0093306	(0.0202618)
GDP-Per-Capita	0.0017237	(0.0108633)	0.0067095	(0.010971)
L.RENC			-0.2796787**	(0.1377434)
Wx				
WTerrorism	0.0658907	(0.0874082)	0.0431276	(0.0873497)
WUrbanization	0.0182295*	(0.0103019)	0.0164405	(0.0110489)
WRents	0.0251198*	(0.0434501)	0.1053283**	(0.0530291)
WGDP-Per-Capita	.0494758*	(0.0291901)	0.0533262	(0.0317579)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12 – Dynamic SDM : Effect in Sahel

VARIABLES	Sahel Dynamic SDM Main	Sahel Dynamic SDM std.error	Non-Sahel Dynamic SDM Main	Non-Sahel Dynamic SDM std.error
Conflict	-0.0341778***	(0.0026684)	-0.218212***	(0.0649652)
urbanization	-0.0198575**	(0.0011724)	0.0184954**	(0.0082169)
Rents	0.0258012	(0.0205773)	-0.0550662	(0.0347964)
GDP-Per-Capita	-0.1015409***	(0.032212)	0.0294549***	(0.0109362)
L.RENC	-0.2413509***	(0.0554945)	-0.1004254 **	(0.0475041)
Wx				
WConflict	-0.0720811***	(0.0021301)	-0.0231651	(0.0444767)
WUrbanization	-0.0367748**	(0.0028258)	0.039884***	(0.0135939)
WRents	0.0447592***	(0.0011214)	-0.0060955	(0.055911)
WGDP-Per-Capita	-0.1582299**	(0.0494175)	0.0688514***	(0.0233379)
Observations	60	60	860	860
Number of ID	03	03	43	43

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

8 Channels

Our main results show that armed conflicts have a significant negative impact on renewable energy consumption in Sub-Saharan Africa, in this section we want so to test the main channels leading to this result. As discussed above, we expect these conflicts to lead to a substitution effect between energy investment and military spending. In other words, we expect to see an increase in the share of the government budget devoted to military spending and a decrease in investment in renewable energy. In addition to these two main channels, these armed conflicts are also expected to have a negative effect on GDP, resulting in a financial undercapacity to invest in green energy. To do this, we simply use spatial regression to see the effect of armed conflict on these three channels.

The results are shown in the table below 13. As we can see, armed conflicts significantly increase military spending, reduce investment in renewable energy, and lower GDP per capita.

Table 13 – Transmission Channels

	Log_GDP_Percapita	Millitary Expenditure	Log_Renewable investment
Conflict	-0.1739852***	0.7477879***	-0.8079365***
	(0.0088436)	(0.1380643)	(0.1285271)
Main Controls	Yes	Yes	Yes
Observations	3263	2946	2995
Number of ID	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

9 Conclusion

This paper analyzes the impact of armed conflicts on the energy transition in 46 Sub-Saharan African countries over the period 2000-2020. It uses a dynamic spatial econometric method to capture the spatial and dynamic effects of these conflicts on renewable energy consumption. Using the dynamic and spatial method of the Durbin model, the main results show that armed conflicts have a significant negative impact on renewable energy consumption. The effect is to 30.97% for the dynamic model against 31.28% for the non-dynamic model. The spatial effects of these conflicts show us that armed conflicts, through their contagion and spillover effects, have a significant and negative impact on renewable energy consumption in the region of 32.11%. The short- and long-term results are generally positive and significant. For heterogeneity, we examine the effects of different types of conflicts and the effects of conflicts in the Sahel. The results show that the effect of terrorism is larger than the effect of other types of conflict. Moreover, the impact of armed conflict on energy transition is greater in the Sahel than in the rest of our sample.

Our results are robust to several tests. First, we change the dependent variable to fossil fuel consumption. This shows that armed conflict increases fossil fuel consumption by 41.8% for the dynamic model. Thus, we can see that the deficit caused by the decrease in renewable energy consumption is quickly offset by the increase in fossil fuel consumption. Next, we change our variable of interest and use the number of deaths caused by armed conflict as a proportion of the total population. The results are the same, showing that armed conflict has a significant negative impact on renewable energy consumption. Finally, we use the other two spatial econometric methods for panel data and add additional control variables. The results are the same, showing that armed conflict has a negative and significant impact on energy transition.

In light of these findings, three main recommendations can be made. First, the fight against armed conflicts must be given priority over energy transition policies. The main findings show that armed conflicts have a significant negative impact on energy transition. Implementing energy transition policies in this region before addressing armed conflicts would be a wasted effort, given the multiple consequences of these conflicts.

Secondly, given the spatial correlation that exists, coordination between the various states in this region will allow us to better combat these armed conflicts and redirect energy transition policies.

Finally, it is imperative to establish specific financing mechanisms to support energy infrastructure projects in conflict-affected areas such as Sahel. Indeed, areas affected by armed conflict are often neglected and lack renewable energy infrastructure. As a result, populations in these areas tend to revert to fossil fuels as a source of consumption, thus penalizing the energy transition.

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Appendix

x

Figure 5 – Armed Conflicts Trend by country

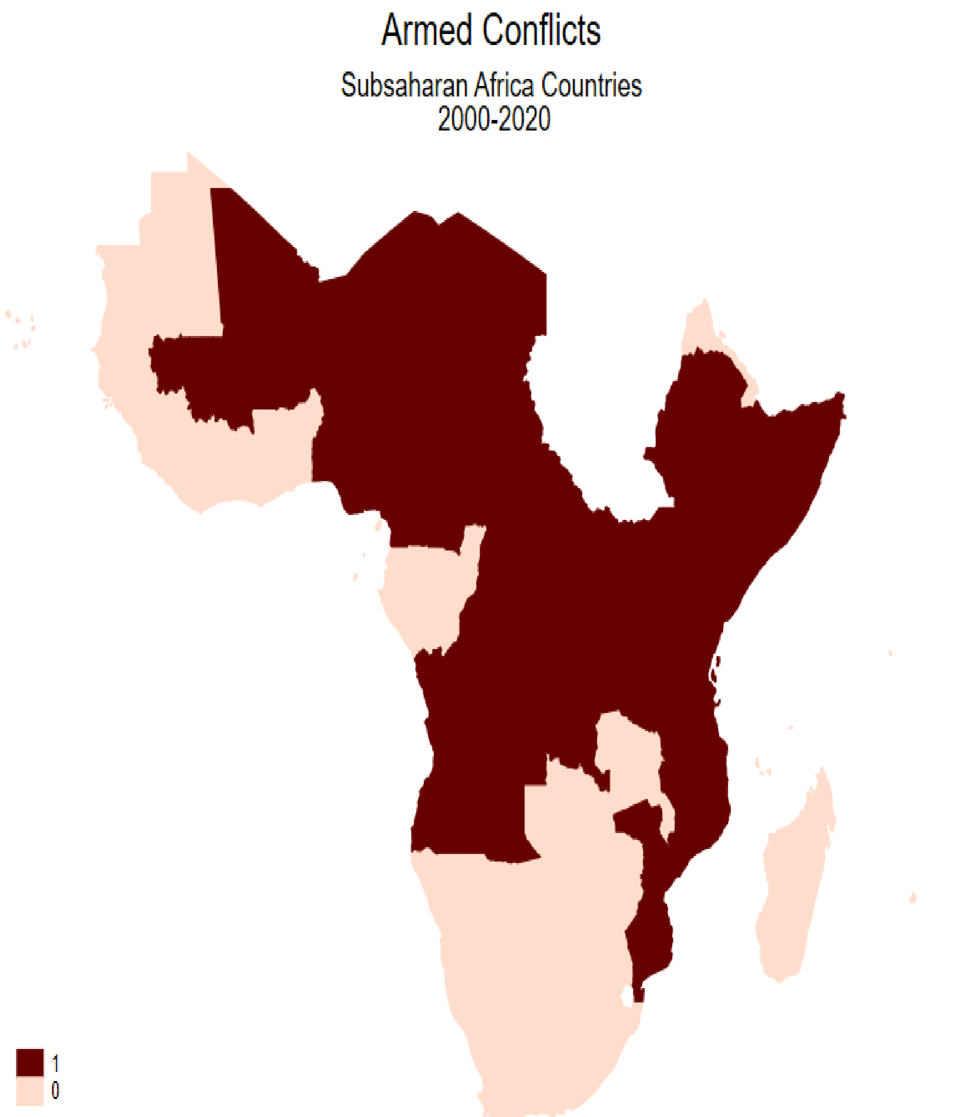
Source : Author

Table 14 – SDM and Dynamic SDM : Effect of other Conflicts

VARIABLES	SDM Main	SDM std.error	Dynamic SDM Main	Dynamic SDM std.error
Other_Conflict	0.0347772	(0.0344834)	0.0375091	(0.0341409)
urbanization	0.0054118	(0.005618)	0.0110106*	(0.0058626)
Rents	0.0265477	(0.0208019)	0.0085679	(0.0205833)
GDP-Per-Capita	0.0042119	(0.0110753)	0.0095585	(0.0110962)
L.RENC			-0.2682756**	(0.1362531)
Wx				
WOther_Conflict	-0.0922635	(0.0631823)	-0.0594885	(0.0633438)
WUrbanization	0.0198897*	(0.0102552)	0.0194587*	(0.0107396)
WRents	0.1504876***	(0.0541318)	0.1504421***	(0.0530291)
WGDP-Per-Capita	0.0495468*	(0.0297673)	0.0575181*	(0.0318593)
Observations	966	966	920	920
Number of ID	46	46	46	46

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 6 – Spatial Distribution of Armed Conflicts



Source : Author

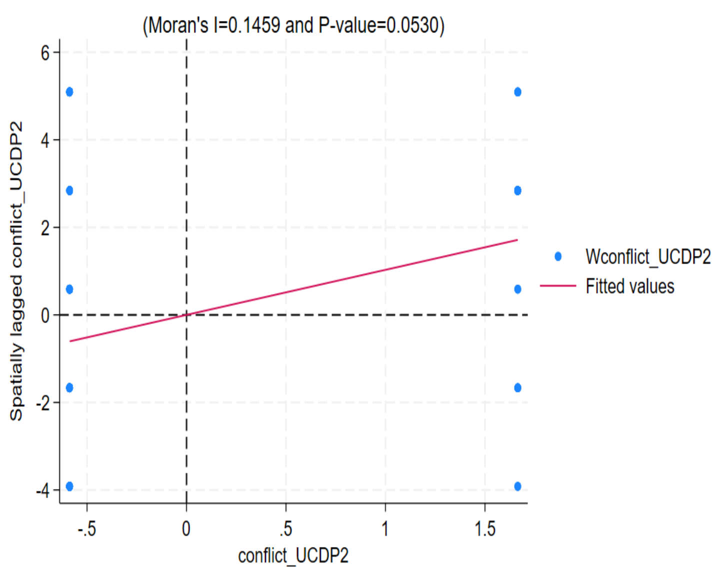
Table 15 – Correlation table

Variables	conflict	GDP	rent	School	Industry	Trade	Fossil Fuel	Pop	Deaths	Urbanization	RENC
conflict	1.000										
GDP-Per-Capita	-0.088	1.000									
rents	0.115	-0.024	1.000								
School	-0.091	0.162	-0.114	1.000							
Industry	-0.106	0.108	-0.029	-0.054	1.000						
Trade	-0.160	0.070	-0.261	0.163	0.260	1.000					
Fossil Fuel	0.026	0.330	-0.141	0.091	0.177	0.103	1.000				
Pop	0.311	0.012	0.052	0.052	-0.016	-0.202	0.036	1.000			
Deaths	-0.501	-0.011	-0.127	0.114	-0.012	0.133	-0.121	-0.383	1.000		
Urbanization	0.044	0.419	-0.114	0.152	0.145	0.059	0.437	0.127	-0.139	1.000	
RENC	-0.096	-0.463	0.103	-0.165	0.047	-0.004	-0.391	-0.072	0.074	-0.529	1.000

Table 16 – Test for model selection

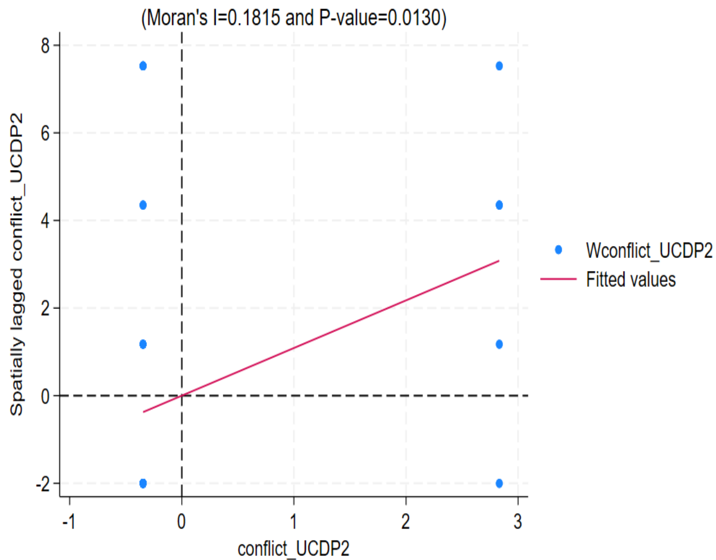
	Chi2	P-value
SDM versus SEM	2.47	0.6492
SDM versus SAR	2.63	0.6221
Hausman Test	208.32	0.0000

Figure 7 – Moran's I scatter plot of Armed Conflicts 2000



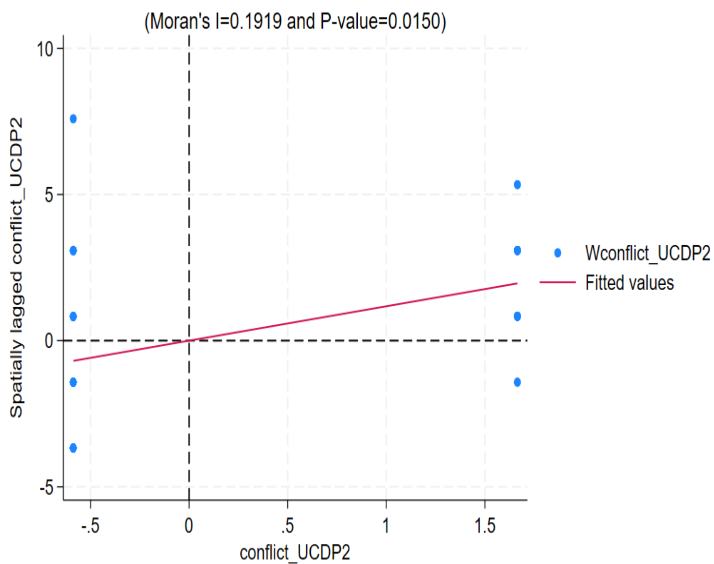
Source : Author

FIGURE 8 – Moran's I scatter plot of Armed Conflicts 2005



Source : Author

FIGURE 9 – Moran's I scatter plot of Armed Conflicts 2015

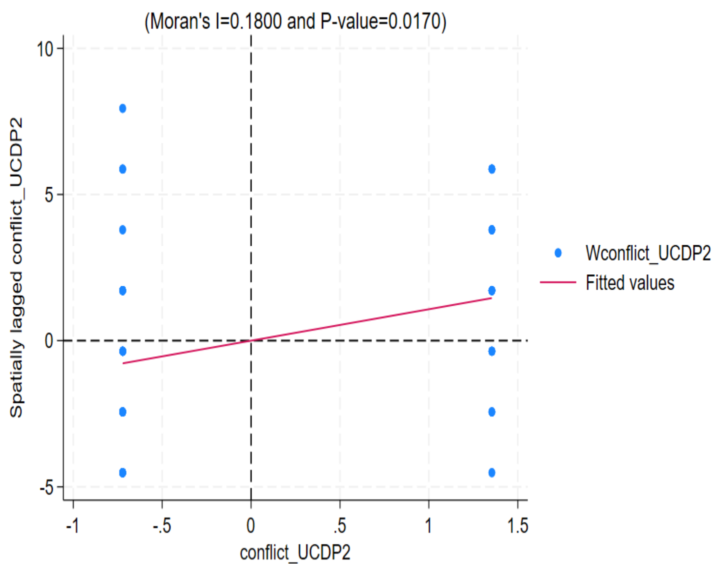


Source : Author

Table 17 – Data

Name	Source
Conflict	https://ucdp.uu.se/downloads/
Urbanization	https://databank.worldbank.org/source/world-development-indicators
Natural Resources rents	https://databank.worldbank.org/source/world-development-indicators
GDP Per capita	https://databank.worldbank.org/source/world-development-indicators
Renewable Energy Consumption	https://databank.worldbank.org/source/world-development-indicators
Fossil Fuel Consumption	https://databank.worldbank.org/source/world-development-indicators
Deaths	https://acleddata.com/
Trade	https://databank.worldbank.org/source/world-development-indicators
Industry	https://databank.worldbank.org/source/world-development-indicators
Human Capital	https://databank.worldbank.org/source/world-development-indicators
Population	https://databank.worldbank.org/source/world-development-indicators
Military Expenditure	https://www.sipri.org/databases
Renewable Investment	https://www.irena.org/Data/Downloads/IRENASTAT

FIGURE 10 – Moran's I scatter plot of Armed Conflicts 2020



Source : Author

TABLE 18 – Countries list

Angola
Benin Botswana Burkina-Faso Burundi Cameroon
Cabo-Verde Central-African Chad Comores Congo Ivory-Coast Congo-Democratic
Djibouti Equatorial-Guinea Eritrea Ethiopia Gabon Gambia Ghana
Guinea Guinea Bissau Kenya Lesotho Liberia Madagascar Malawi Mali Mauritania
Mauritius Mozambique Namibia Niger Nigeria Rwanda Sao-Tome Senegal
Seychelles Sierra-Leone Somalia South-Africa Togo Ouganda
Tanzania Zambia Zimbabwe