The macroeconomic determinants of renewable energy consumption in Madagascar: Evidence from an Autoregressive Distributed Lag modeling approach

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Abstract

We investigate the macroeconomic determinants of renewable energy consumption in Madagascar, using annual data from 1990 to 2021 and the ARDL bounds testing approach. Our results reveal that, in the long run, domestic investment, financial development, trade openness and foreign direct investment have a significant and positive impact on renewable energy consumption. Conversely, increased economic growth, industrial development, income distribution, and carbon emissions lead to a reduction in renewable energy consumption. Therefore, to achieve its ambitious goal of generating 85% of its energy from renewable sources by 2030, the government must carefully monitor and continually analyze these interconnected macroeconomic factors. This will enable effective tailoring of policies and interventions, paving the way for a successful transition to clean and renewable energy.

Keywords: macroeconomic determinant, renewable energy consumption, energy transition, Madagascar

1 Introduction

In today's global context, the imperative to tackle climate change and mitigate greenhouse gas emissions is increasingly acknowledged, underscoring the urgency for effective action. The adoption of renewable energy is of utmost importance, as it serves not only to address environmental concerns but also to promote long-term sustainability and resilience in the face of changing energy demands [89]. The commitment to reduce greenhouse gas emissions by 43% below 2019 levels by 2030 was reaffirmed at the recent COP 28 held in Dubai. This global resolution emphasizes the urgency and collective effort required to combat climate change effectively. Therefore, all stakeholders are invited to take steps to triple renewable energy capacity worldwide and double energy efficiency improvements by 2030 [101]. Madagascar, as an island particularly vulnerable to climate change and environmental issues, including deforestation, biodiversity loss, and energy sustainability challenges, understands this urgency acutely [79, 82, 103].

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The energy sector in Madagascar is currently characterized by a heavy reliance on thermal energy sources, specifically heavy fuel oil and diesel [67, 68, 69]. The high and unpredictable prices of these imported fuels, along with their adverse environmental effects, highlight the necessity for a shift towards alternative energy sources. Given Madagascar's substantial potential for solar, wind, and hydroelectric energy, the promotion of renewable energy offers not only economic opportunities with reduced costs but also significant contributions to enhancing the country's energy independence [63]. Recognizing these pressing challenges, the government has implemented the New Energy Policy 2015–2030 to address them and achieve socio-economic and environmental objectives [57]. By 2030, the New Energy Policy aims to generate 7,900 GWh of electricity, establishing a robust foundation for sustainable energy production. To achieve this goal, the policy emphasizes the development of an energy mix that incorporates renewable energy sources, aiming for up to 85% of the energy mix to be sourced from renewables [56]. By promoting the adoption of renewable energy, Madagascar aims to enhance energy security, reduce greenhouse gas emissions, and foster sustainable development. This transition aligns with global efforts to combat climate change and promote the use of clean and renewable energy across nations [18, 38, 85].

Moreover, Madagascar's renewable energy consumption is influenced by a range of interconnected initiatives that work together to bring about a transformative shift in the country's energy landscape. These initiatives are geared towards driving economic development and improving the overall well-being of the population. In line with the Government's general policy, Madagascar has embarked on an ambitious energy agenda that entails significant endeavors [78, 80]. One key aspect of this agenda is the construction of hydroelectric power stations in Sahofika and Volobe, with a combined capacity of 312 MW [24, 25]. These hydroelectric infrastructures will contribute to the diversification of energy sources and are expected to play a crucial role in meeting the growing demand for electricity in the country. Additionally, efforts are being made to address the financial challenges faced by the national power utility, JIRAMA (Jiro sy Rano Malagasy), with a view to ensuring its stability and effectiveness [80]. The energy strategy also encompasses the hybridization of existing power plants, combining renewable energy sources with conventional ones to improve efficiency and reduce carbon emissions. Furthermore, the deployment of solar parks across all districts is a key component of the plan, aiming to harness the abundant solar resources in the country [31]. To enhance energy access and affordability, a Government program called "Hazavana ho anao" (*light for you*) has been initiated to provide low-cost solar lighting to every household, ensuring that clean energy reaches even the most remote areas [23, 29]. Besides, in order to promote investment in energy management and the responsible use of natural resources, various credit access programs have been established [51, 66, 73, 97, 108]. These programs offer grants and credit solutions to businesses, including renewable energy companies, distributors, and financial institutions involved in the off-grid solar sector. Through these initiatives, companies can secure financing for projects that prioritize environmental performance, energy efficiency, and the adoption of renewable energy sources.

To inform policymakers in Madagascar about the factors influencing the adoption and utilization of renewable energy sources, we propose studying the key macroeconomic determinants of renewable energy consumption. Our empirical study aims to generate data-driven, evidence-based findings that will inform the development of effective policies and strategies for facilitating energy transition planning and promoting renewable energy development in the country. Our analysis considers 12 factors which have been widely studied in both theoretical and empirical research [4, 6, 7, 8, 9, 11, 33, 34, 36, 46, 52, 58, 59, 60, 88, 95]. These factors include carbon emissions (CO2), domestic investment (DINV), economic growth (EG), exchange rate (EXR), financial development (FDEV), foreign direct investment (FDI), income distribution (INC), industry development (IND), inflation (INFL), tourism development (TOUR), trade openness (TR), and urbanization (URB). To evaluate their impact, we propose an empirical model that relates renewable energy consumption (REC) to these various factors:

$$\mathrm{REC} = \mathrm{f}(\mathrm{CO2}, \mathrm{DINV}, \mathrm{EG}, \mathrm{EXR}, \mathrm{FDEV}, \mathrm{FDI}, \mathrm{INC}, \mathrm{IND}, \mathrm{INFL}, \mathrm{TOUR}, \mathrm{TR}, \mathrm{URB}). \tag{1}$$

While previous research by Ramaharo and Randriamifidy [84] adopted feature selection algorithms to estimate (1), the present study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach. This econometric method allows us to analyze both short-run and long-run dynamics while considering potential cointegration among the variables.

2 Data and empirical methodology

Our study uses annual data ranging from 1990 to 2021. They are mainly obtained from the National Institute of Statistics (INSTAT), the Central Bank of Madagascar (BFM), the World Bank database (WDI), and Our World In Data (OWID). We made the complete dataset available on Open Science Framework [83].

Table 1: Variables description.

Variables	Proxy and measurement unit	Source
REC	Renewable energy consumption (% of total final energy consumption)	WDI [104]
CO2	CO2 emission per unit of GDP (kilograms of CO2 per USD constant 2007 GDP)	OWID [71, 87]
DINV	Gross fixed capital formation (% of GDP)	INSTAT [43, 44]
EG	Real gross domestic product (annual percent change)	INSTAT [43, 44]
EXR	Period average exchange rate USD/MGA (annual percent change)	BFM [14]
FDEV	Domestic credit to private sector (% of GDP)	BFM [13, 15]
FDI	Foreign direct investment, net inflows (% of GDP)	BFM [13, 15]
INC	Gross disposable private income (% of GDP)	INSTAT [43]
IND	Industry value added (annual percent change)	INSTAT [43, 44]
INFL	Period average consumer price index (2016 = 100, in a natural logarithm form)	INSTAT [42, 44]
TR	Sum of exports and imports of goods and non-factor services (% of GDP)	BFM [13, 15]
TOUR	Number of tourist arrivals (annual percent change)	INSTAT [44]
URB	Urban population (annual percent change)	WDI [106]

In this study, we apply the linear Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran & Shin [74] and Pesaran et al. [75] to estimate (1). Given the small size of our sample, we cannot fit all the 12 explanatory variables into a single model. Hence, we experimented different combination of variables, then we adopt the following five multivariate regression models which are specified in their respective implicit forms:

$$\begin{aligned}
\text{Model A}: &\quad \mathrm{REC}_t = f(\mathrm{DINV}_t, \mathrm{EG}_t, \mathrm{FDEV}_t, \mathrm{INC}_t);\\
\text{Model B}: &\quad \mathrm{REC}_t = f(\mathrm{CO2}_t, \mathrm{FDEV}_t, \mathrm{IND}_t, \mathrm{TR}_t);\\
\text{Model C}: &\quad \mathrm{REC}_t = f(\mathrm{FDI}_t, \mathrm{IND}_t, \mathrm{INFL}_t, \mathrm{TOUR}_t);\\
\text{Model D}: &\quad \mathrm{REC}_t = f(\mathrm{CO2}_t, \mathrm{IND}_t, \mathrm{INFL}_t, \mathrm{URB}_t);\\
\text{Model E}: &\quad \mathrm{REC}_t = f(\mathrm{DINV}_t, \mathrm{EXR}_t, \mathrm{FDEV}_t, \mathrm{INFL}_t).
\end{aligned}$$

The main advantage of using the ARDL approach is that it can be applied irrespective of the order of integration of the variables (I(0) or I(1), except for the occurrence of I(2)) and it is suitable for small data samples. The ARDL method has also the ability to generate non-biased long-run model estimates [40].

The ARDL forms associated with models A, B, C, D, and E are represented as follows:

Model A

$$\begin{aligned}
\Delta\mathrm{REC}_t = \beta_{A,0} &+ \sum_{i=2}^{p_{A,1}} \beta_{A,1}\Delta\mathrm{REC}_{t-i+1} + \sum_{i=1}^{p_{A,2}} \beta_{A,2}\Delta\mathrm{DINV}_{t-i+1} + \sum_{i=1}^{p_{A,3}} \beta_{A,3}\Delta\mathrm{EG}_{t-i+1} + \sum_{i=1}^{p_{A,4}} \beta_{A,4}\Delta\mathrm{FDEV}_{t-i+1} + \sum_{i=1}^{p_{A,5}} \beta_{A,5}\Delta\mathrm{INC}_{t-i+1}\\
&+ \alpha_{A,1}\mathrm{REC}_{t-1} + \alpha_{A,2}\mathrm{DINV}_{t-1} + \alpha_{A,3}\mathrm{EG}_{t-1} + \alpha_{A,4}\mathrm{FDEV}_{t-1} + \alpha_{A,5}\mathrm{INC}_{t-1} + \varepsilon_{A,t};
\end{aligned}$$

Model B

$$\begin{aligned}
\Delta\mathrm{REC}_t = \beta_{B,0} &+ \sum_{i=2}^{p_{B,1}} \beta_{B,1}\Delta\mathrm{REC}_{t-i+1} + \sum_{i=1}^{p_{B,2}} \beta_{B,2}\Delta\mathrm{CO2}_{t-i+1} + \sum_{i=1}^{p_{B,3}} \beta_{B,3}\Delta\mathrm{FDEV}_{t-i+1} + \sum_{i=1}^{p_{B,4}} \beta_{B,4}\Delta\mathrm{IND}_{t-i+1} + \sum_{i=1}^{p_{B,5}} \beta_{B,5}\Delta\mathrm{TR}_{t-i+1}\\
&+ \alpha_{B,1}\mathrm{REC}_{t-1} + \alpha_{B,2}\mathrm{CO2}_{t-1} + \alpha_{B,3}\mathrm{FDEV}_{t-1} + \alpha_{B,4}\mathrm{IND}_{t-1} + \alpha_{B,5}\mathrm{TR}_{t-1} + \varepsilon_{B,t};
\end{aligned}$$

Model C

$$\begin{aligned}\Delta REC_t &= \beta_{C,0} + \sum_{i=2}^{p_{C,1}} \beta_{C,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{C,2}} \beta_{C,2}\Delta FDI_{t-i+1} + \sum_{i=1}^{p_{C,3}} \beta_{C,3}\Delta IND_{t-i+1} + \sum_{i=1}^{p_{C,4}} \beta_{C,4}\Delta INFL_{t-i+1} + \sum_{i=1}^{p_{C,5}} \beta_{C,5}\Delta TOUR_{t-i+1} \\ &\quad + \alpha_{C,1}REC_{t-1} + \alpha_{C,2}FDI_{t-1} + \alpha_{C,3}IND_{t-1} + \alpha_{C,4}INFL_{t-1} + \alpha_{C,5}TOUR_{t-1} + \varepsilon_{C,t};\end{aligned}$$

Model D

$$\begin{aligned}\Delta REC_t &= \beta_{D,0} + \sum_{i=2}^{p_{D,1}} \beta_{D,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{D,2}} \beta_{D,2}\Delta CO2_{t-i+1} + \sum_{i=1}^{p_{D,3}} \beta_{D,3}\Delta IND_{t-i+1} + \sum_{i=1}^{p_{D,4}} \beta_{D,4}\Delta INFL_{t-i+1} + \sum_{i=1}^{p_{D,5}} \beta_{D,5}\Delta URB_{t-i+1} \\ &\quad + \alpha_{D,1}REC_{t-1} + \alpha_{D,2}CO2_{t-1} + \alpha_{D,3}IND_{t-1} + \alpha_{D,4}INFL_{t-1} + \alpha_{D,5}URB_{t-1} + \varepsilon_{D,t};\end{aligned}$$

Model E

$$\begin{aligned}\Delta REC_t &= \beta_{E,0} + \sum_{i=2}^{p_{E,1}} \beta_{E,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{E,2}} \beta_{E,2}\Delta DINV_{t-i+1} + \sum_{i=1}^{p_{E,3}} \beta_{E,3}\Delta EXR_{t-i+1} + \sum_{i=1}^{p_{E,4}} \beta_{E,4}\Delta FDEV_{t-i+1} + \sum_{i=1}^{p_{E,5}} \beta_{E,5}\Delta INFL_{t-i+1} \\ &\quad + \alpha_{E,1}REC_{t-1} + \alpha_{E,2}DINV_{t-1} + \alpha_{E,3}EXR_{t-1} + \alpha_{E,4}FDEV_{t-1} + \alpha_{E,5}INFL_{t-1} + \varepsilon_{E,t};\end{aligned}$$

where Δ indicates the difference operator, $(p_{i,1}, p_{i,2}, p_{i,3}, p_{i,4}, p_{i,5})$ are the optimal lags, $\beta_{i,0}$ are the intercepts, the beta parameters denote the short-run multipliers, the alpha parameters are the short-run dynamic coefficients, and $\varepsilon_{i,t}$, are the usual error terms, $i = A, B, \ldots, E$.

For each model, the existence of a long-run relationship among the variables can be investigated using the Wald F-test such that the null hypothesis denoted as $H0_i : \alpha_{i,1} = \alpha_{i,2} = \alpha_{i,3} = \alpha_{i,4} = \alpha_{i,5} = 0$ represents the existence of cointegration, while the alternative hypothesis of cointegration is denoted as $H1_i : \alpha_{i,1} \neq \alpha_{i,2} \neq \alpha_{i,3} \neq \alpha_{i,4} \neq \alpha_{i,5} \neq 0$. The calculated F-statistic is compared to the critical values provided by Pesaran et al. [75]. For small sample, as is our case, the calculated F-statistic is compared to the critical values provided by Narayan [62]. There are two sets of critical values: one that applies when all variables are I(0), and the other when the variables are I(1). If the calculated F-statistic is higher than the upper bound of the critical values, then the null hypothesis is rejected irrespective of the order of integration of the variables. If the calculated F-statistic is below the lower bound of the critical values, the null hypothesis cannot be rejected, and hence, we conclude by the absence of cointegration among the variables in the model. If the calculated F-statistic fall between the lower and upper bounds, then the test is inconclusive.

If the variables in the models are cointegrated, the ARDL error correction method, as shown in the following equation, can be used to find the long-run and the short-run coefficients:

Model A

$$\begin{aligned}\Delta REC_t &= \beta_{A,0} + \sum_{i=2}^{p_{A,1}} \beta_{A,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{A,2}} \beta_{A,2}\Delta DINV_{t-i+1} + \sum_{i=1}^{p_{A,3}} \beta_{A,3}\Delta EG_{t-i+1} + \sum_{i=1}^{p_{A,4}} \beta_{A,4}\Delta FDEV_{t-i+1} + \sum_{i=1}^{p_{A,5}} \beta_{A,5}\Delta INC_{t-i+1} \\ &\quad + \varphi_A ECT_{A,t-1} + \varepsilon_{A,t},\end{aligned}$$

Model B

$$\begin{aligned}\Delta REC_t &= \beta_{B,0} + \sum_{i=2}^{p_{B,1}} \beta_{B,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{B,2}} \beta_{B,2}\Delta CO2_{t-i+1} + \sum_{i=1}^{p_{B,3}} \beta_{B,3}\Delta FDEV_{t-i+1} + \sum_{i=1}^{p_{B,4}} \beta_{B,4}\Delta IND_{t-i+1} + \sum_{i=1}^{p_{B,5}} \beta_{B,5}\Delta TR_{t-i+1} \\ &\quad + \varphi_B ECT_{B,t-1} + \varepsilon_{B,t};\end{aligned}$$

Model C

$$\begin{aligned}\Delta REC_t &= \beta_{C,0} + \sum_{i=2}^{p_{C,1}} \beta_{C,1}\Delta REC_{t-i+1} + \sum_{i=1}^{p_{C,2}} \beta_{C,2}\Delta FDI_{t-i+1} + \sum_{i=1}^{p_{C,3}} \beta_{C,3}\Delta IND_{t-i+1} + \sum_{i=1}^{p_{C,4}} \beta_{C,4}\Delta INFL_{t-i+1} + \sum_{i=1}^{p_{C,5}} \beta_{C,5}\Delta TOUR_{t-i+1} \\ &\quad + \varphi_C ECT_{C,t-1} + \varepsilon_{C,t};\end{aligned}$$

Model D

$$\Delta \mathrm{REC}_t = \beta_{D,0} + \sum_{i=2}^{p_{D,1}} \beta_{D,1}\Delta \mathrm{REC}_{t-i+1} + \sum_{i=1}^{p_{D,2}} \beta_{D,2}\Delta \mathrm{CO2}_{t-i+1} + \sum_{i=1}^{p_{D,3}} \beta_{D,3}\Delta \mathrm{IND}_{t-i+1} + \sum_{i=1}^{p_{D,4}} \beta_{D,4}\Delta \mathrm{INFL}_{t-i+1} + \sum_{i=1}^{p_{D,5}} \beta_{D,5}\Delta \mathrm{URB}_{t-i+1}$$
$$+ \varphi_D \mathrm{ECT}_{D,t-1} + \varepsilon_{D,t};$$

Model E

$$\Delta \mathrm{REC}_t = \beta_{E,0} + \sum_{i=2}^{p_{E,1}} \beta_{E,1}\Delta \mathrm{REC}_{t-i+1} + \sum_{i=1}^{p_{E,2}} \beta_{E,2}\Delta \mathrm{DINV}_{t-i+1} + \sum_{i=1}^{p_{E,3}} \beta_{E,3}\Delta \mathrm{EXR}_{t-i+1} + \sum_{i=1}^{p_{E,4}} \beta_{E,4}\Delta \mathrm{FDEV}_{t-i+1} + \sum_{i=1}^{p_{E,5}} \beta_{E,5}\Delta \mathrm{INFL}_{t-i+1}$$
$$+ \varphi_E \mathrm{ECT}_{E,t-1} + \varepsilon_{E,t};$$

where $\mathrm{ECT}_{i,t-i}$, are the lagged error correction terms and φ_i, denote the speed of adjustment, that is the extent to which any disequilibrium in the previous period is being corrected in the present period, $i = A, B, \ldots, E$. A negatively estimated and significant φ parameter implies a correction mechanism on the deviations from the equilibrium.

3 Empirical outcomes and discussion

3.1 Unit root tests

We used the Augmented Dickey-Fuller [22] and Phillips-Perron [76] unit root tests to examine the order of integration of all the variables. We examine the variables at constant, as well as constant with a trend to ensure that none of the variables considered are integrated of order two, i.e., I(2) or beyond. The results presented in Table 2 indicate that some variables like EG, EXR, INC, IND and TOUR are stationary at level. However, all variables are stationary at the first difference with a 1% level of significance, except INFL which is stationary at the first difference with a 5% level of significance. The analysis's mixed stationarity results confirm that ARDL estimation is a better fit for the model.

Table 2: Results of the ADF and PP unit roots tests.

	Augmented Dickey-Fuller (ADF)				**Phillips-Perron (PP)**			
	Constant		Constant and trend		Constant		Constant and trend	
Variables	Level	First diff.	Level	First diff.	Level	First diff.	Level	First diff.
REC	−2.481	−6.080***	−2.619	−5.984***	−2.509	−6.287***	−2.650	−6.182***
CO2	−1.066	−5.717***	−1.803	−5.637***	−1.066	−5.713***	−1.835	−5.634***
DINV	−2.609	−7.688***	−2.801	−7.702***	−2.594	−8.143***	−2.790	−8.665***
EG	−6.790***	−6.824***	−6.751***	−6.806***	−6.878***	−22.149***	−6.851***	−38.584***
EXR	−5.466***	−5.516***	−5.785***	−5.362***	−5.469***	−21.342***	−6.267***	−20.802***
FDEV	−0.324	−5.960***	−0.686	−8.567***	−0.601	−5.913***	−0.412	−8.917***
FDI	−1.552	−4.604***	−1.388	−4.590***	−1.769	−4.599***	−1.691	−4.585***
INC	−5.081***	−9.063***	−4.993***	−8.904***	−5.081***	−20.616***	−4.993***	−21.992***
IND	−6.874***	−6.801***	−6.774***	−6.813***	−6.888***	−17.351***	−6.814***	−28.464***
INFL	−3.169**	−3.099**	−1.467	−3.860**	−6.709***	−3.067**	−1.478	−3.792**
TOUR	−5.514***	−6.423***	−5.837***	−6.385***	−5.510***	−16.190***	−5.913***	−30.519***
TR	−2.521	−7.438***	−3.866**	−7.527***	−2.358	−8.196***	−3.141	−10.697***
URB	−2.130	−5.182***	−2.052	−5.132***	−2.176	−5.182***	−2.100	−5.131***

Note: *** and ** denote statistical significance at 1% and 5%, respectively. The lag lengths for the ADF and PP tests are automatically chosen by Schwarz Information Criteria. The null hypothesis of the ADF and the PP tests is that the series are not stationary.

3.2 ARDL bounds test

The results of the bounds tests are shown in Table 3. The test results showed that the calculated F-statistic for each model is higher than the upper bound I(1) in the 1% significant levels specified by Narayan's critical values for a sample size of 30 [62], confirming the cointegration among the variables.

Table 3: Bounds test for cointegration

Estimated Models	**Lag order**	**F-statistics**
A: $F_{REC}(REC_t \mid DINV_t, EG_t, FDEV_t, INC_t)$	(1, 0, 1, 1, 1)	6.531***
B: $F_{REC}(REC_t \mid CO2_t, FDEV_t, IND_t, TR_t)$	(1, 1, 1, 0, 0)	10.571***
C: $F_{REC}(REC_t \mid FDI_t, IND_t, INFL_t, TOUR_t)$	(1, 1, 0, 1, 1)	5.935***
D: $F_{REC}(REC_t \mid CO2_t, IND_t, INFL, URB_t)$	(1, 1, 0, 0, 1)	11.813***
E: $F_{REC}(REC_t \mid DINV_t, EXR_t, FDEV_t, INFL_t)$	(1, 1, 1, 1, 1)	6.786***
Critical values for F-statistics	**Lower bound** I(0)	**Upper bound** I(1)
10%	2.525	3.560
5%	3.058	4.223
1%	4.280	5.840

Note: *** denotes statistical significance at 1%. Critical values are obtained from Narayan's critical value table [62]. The optimal lag orders are selected using the Hannan–Quinn information criterion.

3.3 Diagnostic and stability tests

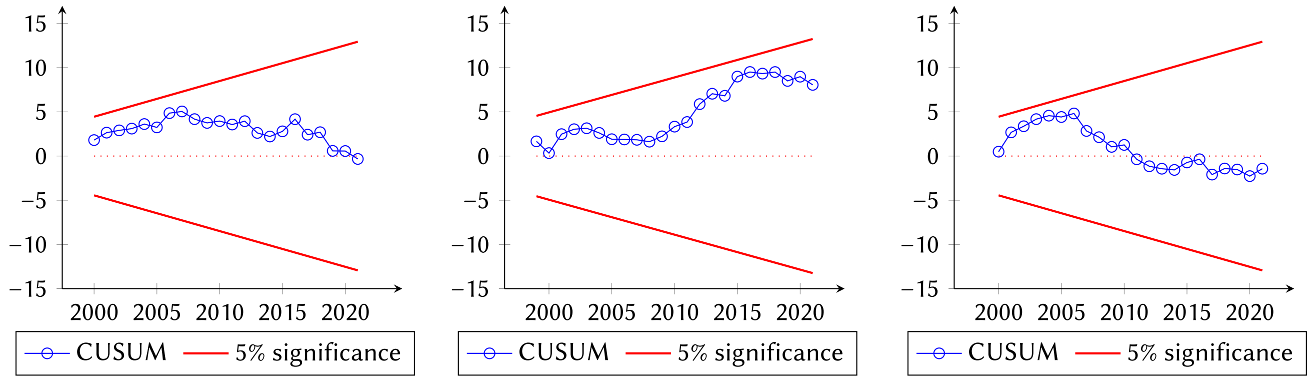
We present the results of the diagnostic tests in Table 4. For each model, we conducted the Jarque-Bera (JB) normality test to check the normality of the residuals. We found that the probability chi-square value is statistically insignificant, suggesting that the residuals are normally distributed. We next conducted the Breusch-Godfrey serial correlation Lagrange Multiplier (LM) test and found that the probability chi-square value is insignificant, meaning we cannot reject the null hypothesis of no serial correlation in the model. While for heteroscedasticity, we conducted the Breusch-Pagan-Godfrey (BPG) heteroscedasticity test and the Autoregressive Conditional Heteroskedasticity (ARCH) test and found both probability chi-square values are not significant, meaning we cannot reject the null hypothesis of homoscedasticity. Finally, we assessed the correct functional form of each model using the Ramsey Regression Specification Error Test (RESET) which confirms that the ARDL model is well-specified.

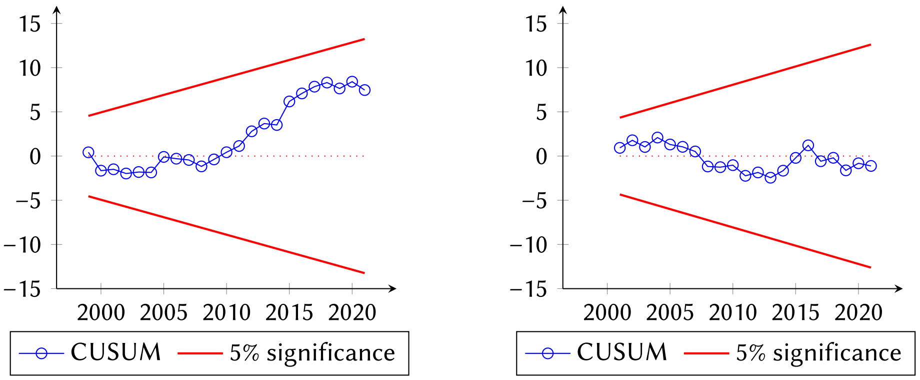
Table 4: Diangostic tests.

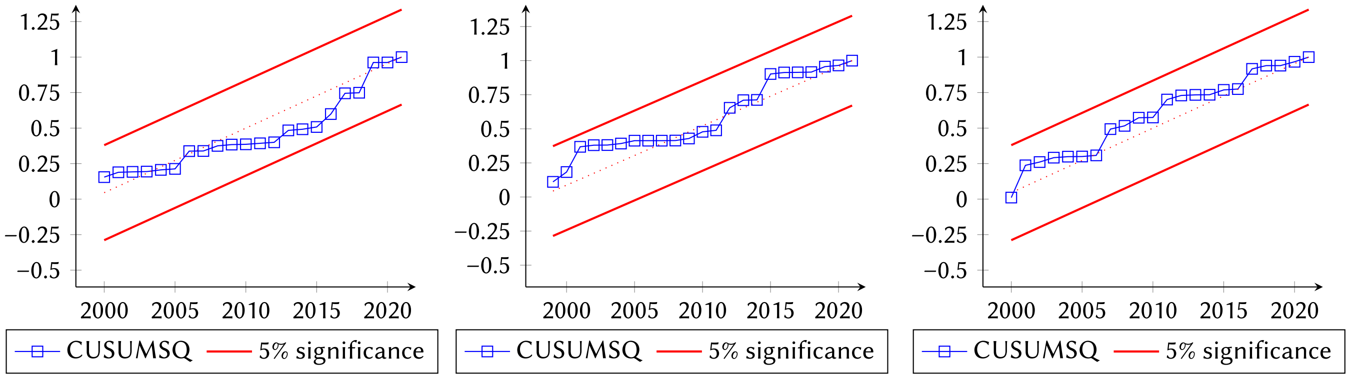
Model	**Normality**	**Serial correlation**	**Heteroscedasticity**		**Functional form**
	χ^2_{JB} [p-value]	χ^2_{LM} [p-value]	χ^2_{BPG} [p-value]	χ^2_{ARCH} [p-value]	χ^2_{RESET} [p-value]
A	0.186 [0.911]	3.877 [0.144]	8.498 [0.386]	0.001 [0.974]	0.214 [0.833]
B	0.707 [0.702]	1.421 [0.491]	8.173 [0.318]	0.705 [0.401]	0.071 [0.944]
C	0.900 [0.638]	0.138 [0.933]	6.834 [0.555]	0.054 [0.817]	0.128 [0.900]
D	0.105 [0.949]	4.325 [0.115]	10.863 [0.145]	1.440 [0.230]	0.341 [0.737]
E	0.496 [0.780]	0.809 [0.667]	5.465 [0.792]	0.034 [0.854]	0.181 [0.858]

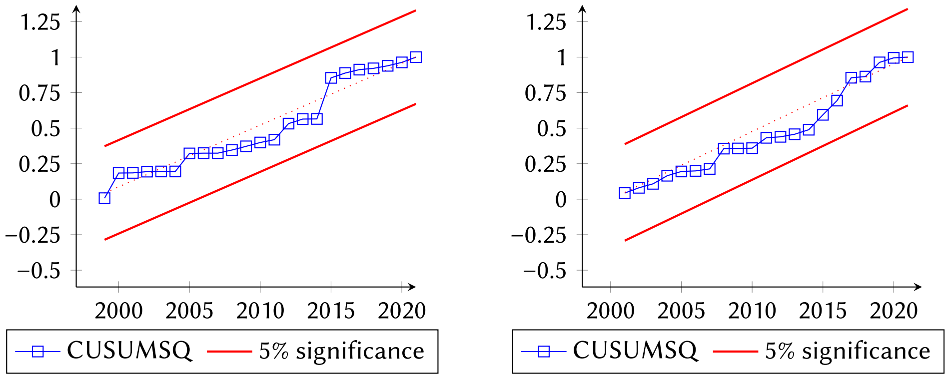
In order to further support the robustness of our results, we check the structural stability of the ARDL estimates using the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) advanced by Brown et al. [16]. Figures 1(a)–1(e) and 1(f)–1(j) show the CUSUM and CUSUMSQ plots of each model, respectively. The plots of each lie within the critical bounds at the 5% level of significance, which indicate the stability of the estimated parameters. These results mean that the models are valid and robust, and can be used in policy and decision-making.

Figure 1: CUSUM and CUSUMSQ plots.


(a) Model A (b) Model B (c) Model C


(d) Model D (e) Model E


(f) Model A (g) Model B (h) Model C


(i) Model D (j) Model E

3.4 ARDL coefficients interpretation

Table 5 shows the long-run and short-run coefficients of the models. Our analysis only considers results statistically significant at the 1% and 5% levels. We first examine the Error Correction Term results. In each model, the coefficient of the lagged Error Correction Term ($\mathrm{ECT}_{i,t-1}$) has the correct range, i.e., lies between −1 and 0, and is statistically significant at the 1% level, indicating a long-run relationship between the variables. Moreover, the models display varying speeds of adjustment towards the long-run equilibrium. Model E exhibits the most rapid adjustment, correcting around 94.6% of the deviation from equilibrium in the previous year within the current year. Conversely, Model D exhibits the slowest adjustment process. Nearly 20.6% of the disequilibrium of the previous year's shock adjusts back to the long-run equilibrium in the current year. Models A, B, and C fall between these two extremes, with annual adjustments of approximately 74.0%, 34.7%, and 63.6% respectively. Consequently, Model E can return to the long-run equilibrium in approximately one year, while Models A, B, C, and D require roughly one year and a third, three years, one and a half years, and five years respectively.

In order to evaluate the goodness-of-fit the short-run models, we examine the adjusted R-squared values. In Model D, it indicates that approximately 94.9% of the variation in REC can be attributed to changes in the amount of carbon emissions, industry development, inflation, and urbanization. Furthermore, a substantial proportion of the change in REC in Model B, at approximately this high percentage, can be explained by variations in the amount of carbon emissions, financial development, industry development and trade openness. In Model A, approximately 70.6% of the variation in REC can be accounted for by changes in the amount of domestic investment, economic growth, financial development, and income distribution. On the other hand, for Models C and E, the regression results indicate that the explanatory variables moderately explain the variations in renewable energy consumption. The adjusted R-squared value for Model C suggests that around 65.0% of the changes in REC can be attributed to variations in the amount of foreign direct investment, industry development, inflation and tourism development. Finally, the adjusted R-squared value for Model E indicates that approximately 61.2% of the changes in REC can be attributed to domestic investment, exchange rate, financial development, and inflation.

Let us now examine the long-run and short-run estimation coefficients allowing us to identify the key determinants of renewable energy consumption in Madagascar, which constitute our main concern.

- **Carbon emissions (**CO2**)**

  Both Model B and Model D consistently demonstrate a negative and statistically significant relationship between CO2 and REC. According to these models, in the long run, REC decreases by 0.270%pt. and 0.200%pt., respectively, as CO2 increases by 1%pt. Furthermore, the short-run impact is also negative and statistically significant, with an even stronger magnitude. According to both models, a 1%pt. increase in CO2 results in a decrease of 0.389%pt. and 0.423%pt. in REC, respectively. These findings are consistent with those observed in studies conducted within the context of Sub-Saharan Africa [65, 92] and bring attention to the significant concerns surrounding developing countries' substantial reliance on fossil fuels, specifically within the transportation sector, which serves as one of the primary sources of greenhouse gas emissions [39]. Additionally, for Madagascar, they shed light on the importance of addressing rural anthropogenic activities, such as deforestation, slash-and-burn agriculture, charcoal production, and land use change, which are clear manifestations of non-sustainable practices [20, 54].

- **Domestic investment (**DINV**)**

  The findings from Model A align with those from Model E regarding the long-run coefficients of DINV. A 1%pt. increase in DINV corresponds to a 0.396%pt. increase in REC in Model A, and a 0.394%pt. increase in REC in Model B. In the short run, Model E suggests a positive effect of DINV on REC, but this effect is not statistically significant. The long-run findings suggest that prioritizing green infrastructure projects, such as the "Volobe" and "Sahofika" hydroelectric plants which are projected to enhance electricity generation from renewable sources by 85% by 2030 [24, 25], has the potential to drive Madagascar's transition towards renewable energy. The Malagasy government further demonstrates its commitment to renewable energy by actively investing in the solar sector [98, 107]. To attract investors, they implemented enticing incentives like exemp-

Table 5: The long-run and short-run estimation results.

	Panel I. Long-run coefficients		**Panel II. Short-run coefficients**	
	Variables	Coefficient (std. error)	Variables	Coefficient (std. error)
Model A	DINV_t	0.396 (0.069)***	ΔDINV_t	–
	EG_t	−0.397 (0.093)***	ΔEG_t	−0.212 (0.026)***
	FDEV_t	0.299 (0.117)**	ΔFDEV_t	−0.074 (0.123)
	INC_t	−0.137 (0.047)***	ΔINC_t	−0.029 (0.015)
	Constant	0.876 (0.047)***	$\text{ECT}_{A,t-1}$	−0.740 (0.107)***
			Adj. R-sq.	0.706
	Variables	Coefficient (std. error)	Variables	Coefficient (std. error)
Model B	CO2_t	−0.270 (0.040)***	ΔCO2_t	−0.389 (0.025)***
	FDEV_t	0.407 (0.107)***	ΔFDEV_t	0.015 (0.054)
	IND_t	−0.145 (0.048)***	ΔIND_t	–
	TR_t	0.060 (0.028)**	ΔTR_t	–
	Constant	0.850 (0.019)***	$\text{ECT}_{B,t-1}$	−0.347 (0.039)***
			Adj. R-sq.	0.940
	Variables	Coefficient (std. error)	Variables	Coefficient (std. error)
Model C	FDI_t	0.284 (0.100)***	ΔFDI_t	0.355 (0.095)***
	IND_t	−0.144 (0.046)***	ΔIND_t	–
	INFL_t	−0.010 (0.004)**	ΔINFL_t	0.037 (0.014)**
	TOUR_t	−0.011 (0.010)	ΔTOUR_t	0.003 (0.003)
	Constant	0.870 (0.016)***	$\text{ECT}_{C,t-1}$	−0.636 (0.096)***
			Adj. R-sq.	0.650
	Variables	Coefficient (std. error)	Variables	Coefficient (std. error)
Model D	CO2_t	−0.200 (0.095)**	ΔCO2_t	−0.423 (0.024)***
	IND_t	−0.236 (0.095)**	ΔIND_t	–
	INFL_t	0.010 (0.006)	ΔINFL_t	–
	URB_t	2.197 (1.173)	ΔURB_t	−0.434 (0.220)
	Constant	0.774 (0.067)***	$\text{ECT}_{D,t-1}$	−0.200 (0.022)***
			Adj. R-sq.	0.949
	Variables	Coefficient (std. error)	Variables	Coefficient (std. error)
Model E	DINV_t	0.394 (0.076)***	ΔDINV_t	0.103 (0.051)
	EXR_t	−0.093 (0.032)***	ΔEXR_t	−0.054 (0.011)***
	FDEV_t	0.427 (0.106)***	ΔFDEV_t	−0.012 (0.152)
	INFL_t	−0.004 (0.003)	ΔINFL_t	0.086 (0.017)***
	Constant	0.745 (0.025)***	$\text{ECT}_{E,t-1}$	−0.946 (0.133)***
			Adj. R-sq.	0.612

Note: ***, ** et * denote statistical significance at 1% and 5%, respectively.

tion from import taxes, streamlined permitting procedures, legal and regulatory framework, and, most notably, opportunities for public-private partnerships [35, 49, 55, 56, 86].

- **Economic growth (**EG**)**

  Model A reveals a significant negative impact of economic growth on REC. The estimation results indicate that a 1%pt. increase in EG leads to a 0.397%pt. decrease in REC. Additionally, the short-run results also demonstrate a negative and significant effect of economic growth on REC, with a 1%pt. increase in EG corresponding to a 0.212%pt. decrease in REC. The long-run findings of our study align with the results of Bekun & Alola [10], who observed similar coefficients in the context of Sub-Saharan Africa. In contrast, their findings indicate a positive effect in the short run. The negative value observed in Sub-Saharan African economies, including Madagascar, for the long-run relationship can be attributed to several factors. Firstly, there is a significant demand for conventional energy sources in these economies, which hinders the adoption of clean energy technologies. Additionally, the cost-related factors associated with implementing clean energy technologies pose a challenge, even as the overall economy improves. Besides, as a developing country, Madagascar relies heavily on fossil fuel-based industries such as mining, textiles, and transportation, which form the backbone of its economy [43, 68]. Additionally, the negative values observed in the short-run relationships in our study can be attributed to the challenges faced by low-income residents, particularly those living in rural settlements, which constitute 60% of the total population as of 2022 [105]. The limited financial resources among these communities create difficulties for governments in distributing energy effectively [64].

- **Exchange rate (**EXR**)**

  In the long run, the exchange rate has a statistically significant negative effect on renewable energy consumption. A 1%pt. increase in the exchange rate corresponds to a 0.093%pt. decrease in REC. This negative relationship between EXR and REC also holds true in the short run, where a 1%pt. increase in EXR corresponds to a 0.054%pt. decrease in REC. These findings align with the studies conducted by Foye [33] in the context of Nigeria, as well as Malik et al. [52] and Sha et al. [90] in the context of Pakistan. These studies interpret the results as indicating a direct relationship between the exchange rate and import costs. In particular, when the exchange rate increases, the cost of imported renewable energy equipment also rises. This, in turn, leads to higher expenses for businesses and the government when investing in clean energy projects. To mitigate this challenge, policymakers might consider exploring strategies to reduce the reliance on imported renewable energy equipment. This could involve promoting local manufacturing of renewable technologies, adopting innovative financing mechanisms, or negotiating favorable trade agreements for key equipment imports [96].

- **Financial development (**FDEV**)**

  Consistently across Models A, B, and E, it is evident that financial development plays a positive and statistically significant role in promoting renewable energy consumption in Madagascar. While there is alignment in the models regarding the positive direction of this relationship, the magnitude of the effect varies. Model A indicates a more modest increase of 0.299%pt. in REC for a 1%pt. increase in FDEV, whereas Models B and E estimate larger increases of 0.407%pt. and 0.427%pt., respectively. Despite the specific magnitudes differing, these findings highlight the potential efficacy of facilitating access to credit for promoting renewable energy solutions and enabling businesses and households to invest in renewable energy projects. Indeed, financial development plays a vital role in promoting renewable energy consumption by increasing investment, mitigating risks, and providing wider access to renewable solutions [5, 48, 91]. In Madagascar, several financial initiatives are driving the expansion of renewable energy and digital services [73]. The Digital and Energy Connectivity for Inclusion in Madagascar Project (DECIM), supported by a $400 million credit from the World Bank, aims to double energy access and add internet users [108]. Through targeted investments and reforms, DECIM plans to provide electricity to 10 million people, connect health centers and schools to renewable energy and digital services, and enable 3.4 million new internet users. Additionally, the Sustainable Use of Natural Resources and Energy Finance (SUNREF), funded by the French Development Agency, promotes green financing and supports renewable energy and energy efficiency initiatives in Madagascar [51, 97]. Furthermore, the Off-Grid Market Development Fund (OMDF), managed by Bamboo Capital Partners in partnership with the World Bank, focuses on expanding access to off-grid solar energy solutions, with the goal of reaching at least 300,000 households and small businesses by 2024 [66].

In contrast to the long-run relationship between FDEV and REC, the short-run effects of FDEV exhibit a mixed sign across the different models. Specifically, in Model A and Model E, FDEV has a negative effect on REC, while in Model B, it has a positive effect. However, these short-run effects are all statistically insignificant.

- **Foreign direct investment (**FDI**)**

  Over the long run, FDI has a positive and significant impact on REC. Based on Model C, a 1%pt. increase in FDI leads to a 0.284%pt. increase in REC. The impact is even stronger in the short-run, where REC increases by 0.355%pt. for a 1%pt. rise in FDI. This finding highlights the potential of actively promoting FDI specifically targeted towards renewable energy as an effective strategy to expedite Madagascar's transition towards a more sustainable energy future. By attracting and facilitating investments in renewable energy projects, Madagascar can not only boost its renewable energy consumption but also foster economic growth and job creation in the renewable energy sector. This aligns with global efforts to attract investment in clean energy technologies and reduce reliance on fossil fuels. In fact, developing countries often rely on FDIs to kick-start their renewable energy sectors by receiving capital, technology transfer, and expertise [12, 21, 77]. An example of the positive impact of FDI on renewable energy can be seen through the actions of Rio Tinto, a mining company operating in Madagascar. Their investment in renewable energy sources, such as solar and wind power plants, showcases how FDI aims to contribute to reducing carbon emissions and attaining sustainable energy objectives [41, 100].

- **Income distribution (**INC**)**

  In Model A, the results indicate that income distribution has a negative and statistically significant impact on renewable energy consumption. Specifically, a 1%pt. increase in INC leads to a decrease of 0.137%pt. in REC. This finding contradicts the study conducted by Nyiwul [64] who found a positive relationship between income and renewable energy consumption in Sub-Saharan Africa. Specifically, in the case of Madagascar, the results indicate that higher incomes do not necessarily lead to a greater willingness to pay for renewable energy sources. This pattern may be attributed to the behavior of the rural population. Many low-income consumers in rural areas lack access to clean energy and rely heavily on kerosene lamps, candles, firewood, and charcoal for their lighting and cooking needs. Additionally, existing technological solutions available in the market are often financially out of reach for a significant portion of the population, making the transition to cleaner energy sources financially unviable for them [61].

- **Industrial development (**IND**)**

  Consistently across Models B, C, and D, there is a clear and statistically significant negative relationship between industrial development and renewable energy consumption. According to these models, a 1%pt. increase in IND is associated with a respective decrease of 0.144%pt., 0.145%pt., and 0.260%pt. in REC. This finding highlights the concerns surrounding Madagascar's heavy reliance on fossil fuels, particularly within its industrial sector. As industrial activity intensifies, the demand for fossil fuels naturally increases, impeding the transition towards cleaner and renewable energy sources. This finding is consistent with the overall understanding of fossil fuel-based economic activities and the importance of diversifying the energy mix and reducing reliance on fossil fuels in the industrial sector. Consequently, there has been a notable increase in investments in cleaner energy alternatives, especially within the textile and mining industries [19, 27, 41, 100]. In the government's general policy for 2024-2029, Madagascar has set its sights on developing emerging sectors to transform the country into an emerging nation with a robust industrial base [80]. The textile sector and agro-industry hold competitive advantages, thanks to preferential access to developed markets such as AGOA (African Growth and Opportunity Act), COMESA (The Common Market for Eastern and Southern Africa), and EPA (Economic Partnership Agreements). As part of this plan, the government aims to implement the ODOF (One District One Factory) project, ensuring that each district has a processing unit tailored to its existing production sectors [32]. Moreover, to address inflation and the trade imbalance, the government recognizes the importance of local production to meet the consumption needs of the population. Based on the concerning findings regarding the negative impact, it is crucial for Madagascar to prioritize the integration of renewable energies into the industrialization process at this stage.

- **Inflation (**INFL**)**

  The impact of inflation on renewable energy consumption varies across the different models. In Model C, INFL has a negative and statistically significant effect, while in Model D, it has a positive but statistically insignificant effect. In Model E, the effect is negative but is statistically insignificant. However, it is important to note that the magnitudes of these effects are relatively small. In Model C, a 1% increase in INFL leads to a decrease in REC of approximately 0.010%pt. In Model D, a 1% increase in INFL results in a negligible increase in REC of around 0.010%pt. In Model E, the impact is even smaller, with a 1% increase in INFL associated with a decrease in REC of about 0.004%pt. These findings suggest that in the long run, inflation plays a minor role in influencing the adoption of renewable energy. However, in the short run, Models C and E, attest that INFL has a positive and statistically significant impact on REC. The magnitude of this impact is also relatively small, 0.037 and 0.086, respectively. This implies that in the short run, a 1% increase in INFL leads to an increase in REC of about 0.037%pt. to 0.086%pt.This situation can be explained as follows. Inflation in Madagascar is largely influenced by the prices of energy and food items [2]. Energy products alone account for a significant 7.8% share of the overall consumer price index [45]. As a result, households and businesses are actively exploring more stable and cost-effective alternatives to mitigate the impact of rising energy prices. However, it is important to note that this shift towards renewable energy solutions is more likely to occur among higher-income consumers are often more environmentally conscious and willing to pay a premium for clean energy options [93]. To further support this observation, as prices rise, low-income consumers are more likely to prioritize spending on essential food items for subsistence, with the adoption of clean energy, as mentioned earlier, becoming a secondary consideration due to affordability constraints [61].

- **Tourism development (**TOUR**)**

  The long-run impact of tourism development on renewable energy consumption is found to be negative, while the short-run effect shows a small positive association. However, we note that both the long-run and short-run effects are statistically insignificant. These findings indicate that while ecotourism and sustainable tourism can have a positive impact in the short run, further investment in green tourism is needed to encourage renewable energy consumption. Despite government and private sector efforts to promote clean energy within the tourism industry [3, 37, 94], the findings suggest that the current state of the tourism industry still hinders the adoption of renewable energy. To address this challenge, it is important to focus on expanding and improving green tourism practices. This can be achieved through policies and incentives that encourage tourism establishments to adopt renewable energy technologies and by investing in infrastructure that supports the integration of renewable energy sources. This action will also improve the economic well-being of local communities by providing them with sustainable and environmentally friendly energy sources [17]. Additionally, raising awareness and providing education about the benefits of renewable energy in the tourism sector play also a crucial role in the adoption of sustainable practices [53]. Fortunately, Madagascar, through the general state program 2024-2029, aims to become a globally recognized tourist destination for the sustainable management of its exceptional wealth of natural, cultural and human heritage [80].

- **Trade openness (**TR**)**

  Trade openness exerts a positive and statistically significant influence on Madagascar's renewable energy consumption, although the effect size is relatively modest. From Model B, a 1%pt. increase in trade openness corresponds to a 0.060%pt. increase in renewable energy consumption (REC). The results agree with those of Lawal [50] in the context of Sub-Saharan African economies but contradicts those of Ramaharo and Randriamifidy [84] who obtain negative relation in the context of Madagascar. The positive relation likely reflects the role of trade in facilitating the importation of renewable energy equipment and technologies, which in turn supports the expansion of renewable energy infrastructure in the country. It is important to note that the government plays an active role in stimulating the import of renewable energy equipment by encouraging private investment in clean and sustainable energy. This is achieved through the provision of generous tax incentives, especially for start-ups and Small and Midsize Enterprises, such as exemptions from value-added tax (VAT) and import duties for solar panels, wind turbines, and batteries [26, 30, 81]. These incentives encourage private entities to invest in renewable energy projects and contribute to the expansion of Madagascar's renewable energy sector. The positive relationship between trade openness and renewable energy consumption not only highlights Madagascar's engagement with global sustainability trends but also suggest that international and regional trade agreements support the adoption of renewable energy in Madagascar.

- **Urbanization (**URB**)**

  In Model D, the long-run effect of urbanization on renewable energy consumption is positive but statistically insignificant, while in the short run, the effect is negative but also statistically insignificant. However, there are potential explanations for this mixed outcome. In the short run, rapid urbanization can lead to increased road transport demand, which in turn drives higher fossil fuel consumption [72, 102], as well as elevated carbon dioxide emissions in urban areas [1, 28]. Transportation-related fuel consumption in Madagascar typically accounts for a significant portion of total petroleum consumption in the petroleum market [68]. In the long run, higher population density in urban areas facilitates the development of grid infrastructure, while increased awareness and access to technology among urban residents may encourage them to adopt cleaner energy solutions [47].

Our research findings are consistent with the study conducted by Ramaharo and Randriamifidy [84] regarding specific determinants. They employed feature selection algorithms to identify the primary factors influencing the adoption of renewable energy consumption. According to their findings, domestic investment, foreign direct investment, and inflation positively contribute to the adoption of renewable energy. Conversely, their study revealed that industrial development and trade openness have a detrimental impact on renewable energy consumption in Madagascar. When examining the negative impact of trade openness, they focused specifically on the perspective of exports. They explained that this negative relationship can be attributed to the infrastructure and transportation systems used in the production of export goods, particularly minerals, which are not yet fully aligned with energy-efficient or renewable energy technologies. In line with the findings of Opeyemi et al. [70], it is further supported that the negative impact of trade openness on renewable energy adoption in Sub-Saharan African economies can be attributed to the type of exports they engage in. Indeed, Sub-Saharan African countries primarily rely on non-agricultural primary exports, which are often associated with polluting and non-sustainable activities [99].

4 Conclusion

This study aimed to investigate the macroeconomic factors influencing renewable energy consumption in Madagascar using annual data from 1990 to 2021 and the ARDL bounds testing approach. The findings revealed both positive and negative associations between the identified factors and renewable energy consumption.

On the positive side, domestic investment, financial development, trade openness, and foreign direct investment were found to have a significant and positive impact on renewable energy consumption in the long run. This suggests that ongoing efforts to promote energy transition, such as investing in green infrastructure, providing credit support for renewable projects, offering tax incentives for importing renewable equipment, and attracting foreign direct investment focused on energy sustainability and carbon emission reduction goals, have the potential to facilitate Madagascar's energy transition.

On the negative side, higher economic growth, industrial development, income distribution, and carbon emissions were found to be associated with a decline in renewable energy consumption. This indicates that many businesses in Madagascar still heavily rely on conventional energy sources for their production processes. Therefore, various incentives such as subsidies, green loans, and grid modernization to encourage the private sector to transition to renewable energy should be implemented. These measures aim to reduce costs and improve the necessary infrastructure for integrating renewable energy sources into their operations.

Additionally, the study highlights the consumer preference for cheaper and more readily available energy sources, even if they are environmentally polluting, over cleaner but less familiar renewable alternatives, particularly among low-income consumers. One potential solution to address this issue involves the adoption of energy efficiency programs and the implementation of public awareness campaigns. Energy efficiency programs can help reduce overall energy consumption, thereby enhancing the impact of renewable energy sources. Public awareness campaigns play a crucial role in educating consumers about the significant benefits of renewable energy and empowering them to make informed choices aligned with sustainability objectives.

Overall, these findings suggest that a comprehensive approach encompassing both supply-side incentives for businesses and demand-side initiatives targeting consumer behavior is necessary to promote renewable energy consumption in Madagascar and achieve a sustainable energy transition.

References

[1] Frank Adusah-Poku (2016), "Carbon dioxide emissions, urbanization and population: Empirical evidence in Sub-Saharan Africa", *Energy Economics Letters*, **3**(1), 1–16. [Cited on page 13.]

[2] AfDB – African Development Bank (2023a), "Madagascar Economic Outlook", Retrieved October 10, 2023, from `https://www.afdb.org/en/knowledge/publications/african-economic-outlook` [Cited on page 12.]

[3] AfDB – African Development Bank (2023b), "Madagascar - Nosy Be Renewable Energy Power Project Preparation – Project Completion Report" (August 10, 2023). Retrieved December 10, 2023, from `https://www.afdb.org/en/documents/madagascar-nosy-be-renewable-energy-power-project-preparation-project-completion-report` [Cited on page 12.]

[4] Hamdy A. A. Alhendawy, Mohammed G. Abdallah Mostafa, Mohamed I. Elgohari, Ibrahim A. A. Mohamed, Nabil M. A. Mahmoud & Mohamed A. Mohamed (2023), "Determinants of renewable energy production in Egypt. New approach: Machine learning algorithms", *International Journal of Energy Economics and Policy*, **13**(6), 679–689. [Cited on page 2.]

[5] Sorin G. Anton & Anca E. A. Nucu (2020), "The effect of financial development on renewable energy consumption. A panel data approach", *Renewable Energy*, **147**(Part 1), 330–338. [Cited on page 10.]

[6] Mohd Arshad Ansari, Salman Haider & Tariq Masood (2021), "Do renewable energy and globalization enhance ecological footprint: an analysis of top renewable energy countries?", *Environmental Science and Pollution Research*, **28**, 6719–6732. [Cited on page 2.]

[7] Muhammad Azam, Abdul Qayyum Khan, Eleni Zafeiriou & Garyfallos Arabatzis (2016), "Socio-economic determinants of energy consumption: An empirical survey for Greece", *Renewable and Sustainable Energy Reviews*, **57**, 1556–1567. [Cited on page 2.]

[8] Narges Bamati & Ali Raoofi (2020), "Development level and the impact of technological factor on renewable energy production", *Renewable Energy*, **151**, 946–955. [Cited on page 2.]

[9] Sadia Bano, Mehtab Alam, Anwar Khan & Lu Liu (2011), "The nexus of tourism, renewable energy, income, and environmental quality: an empirical analysis of Pakistan", *Environment, Development and Sustainability*, **23**, 14854–14877. [Cited on page 2.]

[10] Festus V. Bekun & Andrew A. Alola (2022), "Determinants of renewable energy consumption in agrarian Sub-Sahara African economies", *Energy, Ecology and Environment*, **7**, 227–235. [Cited on page 10.]

[11] Mehdi Ben Jebli, Slim Ben Youssef & Nicholas Apergis (2019), "The dynamic linkage between renewable energy, tourism, CO2 emissions, economic growth, foreign direct investment, and trade", *Latin American Economic Review*, **28**(2), 1–19. [Cited on page 2.]

[12] Muhammed Benli (2021), "Foreign direct investment and energy consumption in developing economies: An Analysis of heterogeneous dynamic panel data models with cross sectional dependency", *Balkan Sosyal Bilimler Dergisi*, **10**(20), 18–27. [Cited on page 11.]

[13] BFM – Banky Foiben'i Madagasikara, "Bulletin de la BFM". Retrieved July 01, 2023, from `https://www.banky-foibe.mg/vente_bulletin-de-bfm` [Cited on page 3.]

[14] BFM – Banky Foiben'i Madagasikara, "Marché de Changes". Retrieved July 01, 2023, from `https://www.banky-foibe.mg/marche_marche-de-change#recherche-taux-de-change` [Cited on page 3.]

[15] BFM – Banky Foiben'i Madagasikara, "Rapport Annuel". Retrieved July 01, 2023, from `https://www.banky-foibe.mg/_rapport-annuel` [Cited on page 3.]

[16] Robert L. Brown, James Durbin & James M. Evans (1975), "Techniques for testing the constancy of regression relationships over time", *Journal of the Royal Statistical Society: Series B (Methodological)*, **37**, 149–163. [Cited on page 6.]

[17] Thorkil Casse, Manitra H. Razafintsalama & Aanders Milhøj (2022), "A trade-off between conservation, development, and tourism in the vicinity of the Andasibe-Mantadia National Park, Madagascar", *SN Social Sciences*, **2**(12), 1–28. [Cited on page 12.]

[18] Angéline Chartier & Moïse Tsayem Demaze (2020), "L'Afrique dans l'agenda international de réduction des émissions de gaz à effet de serre: quelle transition énergétique pour quel développement? L'exemple de Madagascar", *Mondes en développement*, **192**(4), 71–88. [Cited on page 2.]

[19] Ciel Textile, "Sustainability report 2022. Winning Well". Retrieved October 10, 2023, from`https://cieltextile.com/Sustainability-Report-2022.pdf` [Cited on page 11.]

[20] Megan Clark (2012), "Deforestation in Madagascar: Consequences of population growth and unsustainable agricultural processes", *Global Majority E-Journal*, **3**(1), 61–71. [Cited on page 8.]

[21] Ranti Darwin, Dyah W. Sari & Unggul Heriqbaldi (2022), "Dynamic linkages between energy consumption, foreign direct investment, and economic growth: A New insight from developing countries in Asia", *International Journal of Energy Economics and Policy*, **12**(6), 30–36. [Cited on page 11.]

[22] David A. Dickey & Wayne A. Fuller (1979), "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, **74**(366), 427–43 [Cited on page 5.]

[23] Direction de la Communication, "Allocution du Président de la République de Madagascar au Sommet Mondial des Gouvernements à Dubaï, Émirats Arabes Unis", *Présidence de la République de Madagascar* (February 13, 2024). Retrieved February 14, 2024, from `https://www.presidence.gov.mg/actualites/2041-allocution-du-president-de-la-republique-de-madagascar-au-sommet-mondial-des-gouvernements-a-dubai-emirats-arabes-unis.html` [Cited on page 2.]

[24] Direction de la Communication et des Relations Publiques, "Signature des contrats du projet Sahofika et PRIRTEM 2", *Présidence de la République de Madagascar* (November 15, 2021). Retrieved October 01, 2023, from `https://www.presidence.gov.mg/actualites/1443-signature-des-contrats-du-projet-sahofika-et-prirtem-2.html` [Cited on pages 2 and 8.]

[25] Direction de la Communication et des Relations Publiques, "Palais d'Etat d'Iavoloha: Signature du Projet Volobe Amont", *Présidence de la République de Madagascar* (May 26, 2023). Retrieved October 01, 2023, from `https://www.presidence.gov.mg/actualites/1896-palais-d-etat-d-iavoloha-signature-du-projet-volobe-amont.html` [Cited on pages 2 and 8.]

[26] Direction Générale des Impôts, "Incitations fiscales pour les start-ups et les PME. Secteur Energie Renouvelable". Retrieved December 01, 2023, from `https://www.impots.mg/public/wysiwyg/upload/files/energie%20renouvelable.pdf` [Cited on page 13.]

[27] EDBM – Economic Development Board of Madagascar, "Une zone industrielle dédiée au textile", In: *Yearbook Rapport Économique. Madagascar 2021, L'Émergence Malagsy*, EDBM, 2021. [Cited on page 11.]

[28] Ekpeno Effiong (2016), "Urbanization and environmental quality in Africa", *Munich Personal RePEc Archive*, **73224**, University Library of Munich, Germany, 2016. [Cited on page 13.]

[29] L'Express de Madagascar, "Projet hazavana ho anao - Des foyers voient la lumière" (September 07, 2020). Retrieved August 23, 2023, from `https://lexpress.mg/07/09/2020/projet-hazavana-ho-anao-des-foyers-voient-la-lumiere/` [Cited on page 2.]

[30] L'Express de Madagascar, "Investir dans les énergies renouvelables - Nouveau dispositif incitatif en place" (November 14, 2022). Retrieved August 23, 2023 from `https://lexpress.mg/14/11/2022/investir-dans-les-energies-renouvelables-nouveau-dispositif-incitatif-en-place/` [Cited on page 13.]

[31] L'Express de Madagascar, "Projet de centrales solaires - Une course contre la montre engagée" (May 16, 2023). Retrieved August 23, 2023, from `https://lexpress.mg/16/05/2023/projet-de-centrales-solaires-une-course-contre-la-montre-engagee/` [Cited on page 2.]

[32] L'Express de Madagascar, "Développement - La souveraineté industrielle en bonne voie" (February 03, 2024). Retrieved February 17, 2023, from `https://lexpress.mg/16/05/2023/projet-de-centrales-solaires-une-course-contre-la-montre-engagee/` [Cited on page 11.]

[33] Victoria O. Foye (2023), "Macroeconomic determinants of renewable energy penetration: Evidence from Nigeria", *Total Environment Research Themes*, **5**, 1–13. [Cited on pages 2 and 10.]

[34] Giray Gozgor, Mantu Kumar Mahalik, Ender Demir & Hemachandra Padhan (2020), "The impact of economic globalization on renewable energy in the OECD countries", *Energy Policy*, **139**, 1–13. [Cited on page 2.]

[35] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2016), Madagascar: Opportunities for Solar Business, Federal Ministry for Economic Affairs and Energy (BMWi). [Cited on page 9.]

[36] Florian Grosset & Phu Nguyen-Van (2016), "Consommation d'énergie et croissance économique en Afrique subsaharienne", *Mondes en Développement*, **176**(4), 25–42. [Cited on page 2.]

[37] Sandra M. Hafalianavalona, "Développement – L'énergie verte en soutien au tourisme", *L'Express de Madagascar* (June 22, 2017). Retrieved September 10, 2023, from `https://lexpress.mg/22/06/2017/developpement-lenergie-verte-en-soutien-au-tourisme/` [Cited on page 12.]

[38] Imran Hanif (2018), "Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in Sub-Saharan Africa", *Environmental Science and Pollution Research*, **25**, 15057–15067. [Cited on page 2.]

[39] Gary Haq & Dieter Schwela (2012), *Transport and Environment in Sub-Saharan Africa*, The TEST Network. [Cited on page 8.]

[40] Richard Harris & Robert Sollis (2003), *Applied Time Series Modelling and Forecasting*, John Wiley and Sons, Chichester. [Cited on page 3.]

[41] Mirana Ihariliva, "Énergies renouvelables - Une centrale solaire-éolienne pour RIO TINTO-QMM", *L'Express de Madagascar* (December 11, 2021). Retrieved September 10, 2023, from `https://lexpress.mg/11/12/2021/energies-renouvelables-une-centrale-solaire-eolienne-pour-rio-tinto-qmm/` [Cited on page 11.]

[42] INSTAT – Institut National de la Statistique, "Indice des prix à la Consommation (IPC)", *Wayback Machine* (January 20, 2022). Retrieved August 10, 2023, from `https://web.archive.org/web/20220120074937/https://www.instat.mg/statistiques/bases-de-donnees/nipc` [Cited on page 3.]

[43] INSTAT – Institut National de la Statistique, "Comptes Nationaux", *Wayback Machine* (December 28, 2021) Retrieved August 10, 2023, from `https://web.archive.org/web/20211228223849/https://www.instat.mg/statistiques/bases-de-donnees/comptes-nationaux` [Cited on pages 3 and 10.]

[44] INSTAT – Institut National de la Statistique, "Tableau de Bord de l'Économie", *Wayback Machine* (September 28, 2022) Retrieved August 10, 2023, from `https://web.archive.org/web/20220928222805/http://www.instat.mg/thematique/economie` [Cited on page 3.]

[45] INSTAT – Institut National de la Statistique (2019), *Le nouvel Indice des Prix à la Consommation*, INSTAT, Direction des Statistiques des Conditions de Vie des Ménages, Madagascar. [Cited on page 12.]

[46] Shahid Iqbal, Ying Wang, Sharafat Ali, Muhammad A. Haider & Nabila Amin (2023), "Shifting to a green economy: Asymmetric macroeconomic determinants of renewable energy production in Pakistan", *Renewable Energy*, **202**, 234–241. [Cited on page 2.]

[47] IRENA – International Renewable Energy Agency (2020), *Rise of renewables in cities: Energy solutions for the urban future*, International Renewable Energy Agency, Abu Dhabi. [Cited on page 13.]

[48] Dervis Kirikkaleli & Tomiwa S. Adebayo (2021), "Do renewable energy consumption and financial development matter for environmental sustainability? New global evidence", *Sustainable Development*, **29**, 583–594. [Cited on page 10.]

[49] Jon Lan, Micol Salmeri, Benjamin Curnier & Yuri L. Hamden (2019), *Mini-Grid Market Opportunity Assessment: Madagascar*, Green Mini-Grids Market Development Programme Document Series, African Development Bank Group. [Cited on page 9.]

[50] Adedoyin I. Lawal (2023), "Determinants of renewable energy consumption in Africa: Evidence from system GMM", *Energy*, **16**, 1–19. [Cited on page 12.]

[51] Malagasy News, "Crédit Sunref: Une enveloppe de six millions d'euros pour les projets écoresponsables", *Malagasy News* (April 13, 2021). Retrieved October 10, 2023, from `https://malagasynews.com/economie/10340/` [Cited on pages 2 and 10.]

[52] Ihtisham A. Malik, Ghamz-e-Ali Siyal, Alias B. Abdullah, Arif Alam, Khalid Zaman, Phouphet Kyophilavong, Muhammad Shahbaz, Siraj Ullah Baloch & Tauqeer Shams (2014), "Turn on the lights: Macroeconomic factors affecting renewable energy in Pakistan", *Renewable and Sustainable Energy Reviews*, **38**, 277–284. [Cited on pages 2 and 10.]

[53] Anobua A. A. Martial, Huang Dechun, Liton C. Voumik, Md. Jamsedul Islam & Shapan C. Majumder (2023). "Investigating the influence of tourism, GDP, renewable energy, and electricity consumption on carbon emissions in low-income countries", *Energies*, **16**(12), 1–28. [Cited on page 12.]

[54] MEEH – Ministère de l'Environnement, de l'Écologie et des Forêts (2018), Stratégie Nationale REDD+ Madagascar, MEEF - BNC-REDD+, Madagascar. [Cited on page 8.]

[55] MEF – Ministère de l'Economie et des Finances, "Présentation du RLSF – un dispositif pour le secteur de l'énergie renouvelable visant à accompagner le pays dans la réalisation de ses objectifs énergétiques" (April 15, 2019). Retrieved October 15, 2023, from `http://mail.mfb.gov.mg/page_personnalisee/index/news/88` [Cited on page 9.]

[56] MEH – Ministère de l'Energie et des Hydrocarbures, "Energie Renouvelable. Gouvernance Energetique". Retrieved September 22, 2023, from `https://meh.mg/agir-2/energie-renouvelable/` [Cited on pages 2 and 9.]

[57] MEH – Ministère de l'Énergie et des Hydrocarbures (2015), *Lettre de Politique de l'Énergie de Madagascar 2015–2030*, MEH, Madagascar. [Cited on page 2.]

[58] Nora Y. Mohamed Yusoff, Abdul R. Ridzuan, Thomas Soseco, Wahjoedi, Bagus S. Narmaditya & Lim C. Ann (2023), "Comprehensive outlook on macroeconomic determinants for renewable energy in Malaysia", *Sustainability*, **15**(5), 1–15. [Cited on page 2.]

[59] Md. Monirul Islam, Muhammad Irfan, Muhammad Shahbaz & Xuan V. Vo (2022), "Renewable and non-renewable energy consumption in Bangladesh: The relative influencing profiles of economic factors, urbanization, physical infrastructure and institutional quality", *Renewable Energy*, **184**, 1130–1149. [Cited on page 2.]

[60] Muntasir Murshed & Md. Shabbir Alam (2021), "Estimating the macroeconomic determinants of total, renewable, and non-renewable energy demands in Bangladesh: the role of technological innovations", *Environmental Science and Pollution Research*, **28**, 30176–30196. [Cited on page 2.]

[61] Kameshnee Naidoo & Christiaan Loots (2020), *Madagascar. Energy and the Poor: Unpacking the Investment Case for Clean Energy*, UN Capital Development Fund (UNCDF). [Cited on pages 11 and 12.]

[62] Paresh K. Narayan (2005), "The saving and investment nexus for China: evidence from cointegration tests", *Applied Economics*, **37**(17), 1979–1990. [Cited on pages 4 and 6.]

[63] Modeste K. Nematchoua (2021), "Analysis and comparison of potential resources and new energy policy of Madagascar island; A review", *Renewable Energy*, **171**, 747–763. [Cited on page 2.]

[64] Linus Nyiwul (2016), "Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in Sub-Sahara Africa", *Clean Technologies and Environmental Policy*, **19**, 437–450. [Cited on pages 10 and 11.]

[65] Sydney Oluoch, Pankaj Lal & Andres Susaeta (2021), "Investigating factors affecting renewable energy consumption: A panel data analysis in Sub Saharan Africa'', *Environmental Challenges*, **4**, 1–10. [Cited on page 8.]

[66] OMDF – Off-Grid Market Development Fund, "The opportunities of the off-grid solar market in Madagascar". Retrieved September 30, 2023, from `https://omdf.mg/public/uploads/2020/11/Fr-OMDF-press-release-2020-11-11-final.pdf` [Cited on pages 2 and 10.]

[67] OMH – Office Malgache des Hydrocarbures, "Bulletin Pétrolier". Retrieved August 10, 2023, from `http://www.omh.mg/index.php?idm=5&CL=bulpetro` [Cited on page 2.]

[68] OMH – Office Malgache des Hydrocarbures (2023a), "Ventes nationales de produits pétroliers par composante (2016–2022)" [Unpublished raw data], OMH, Madagascar. [Cited on pages 2, 10, and 13.]

[69] OMH – Office Malgache des Hydrocarbures (2023b), "Ventes nationales de produits pétroliers par composante (2016–2022)" [Unpublished raw data], OMH, Madagascar. [Cited on page 2.]

[70] Akinyemi Opeyemi, Efobi Uchenna, Asongu Simplice & Osabuohein Evans (2019), "Renewable energy, trade performance and the conditional role of finance and institutional capacity in sub-Sahara African countries", *Energy Policy*, **132**, 490–498. [Cited on page 13.]

[71] OWID – Our World in Data, "Madagascar: CO2 Country Profile". Retrieved August 10, 2023, from `https://ourworldindata.org/co2/country/madagascar` [Cited on page 3.]

[72] Jyoti Parikh & Vibhooti Shukla (1995), "Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries", *Global Environmental Change*, **5**(2), 87–103. [Cited on page 13.]

[73] PERER – Promotion de l'Électrification par les Énergies Renouvelables (2020), *Financement des projets d'énergies renouvelables à Madagascar*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH – Programme "Promotion de l'Électrification par les Énergies Renouvelables". [Cited on pages 2 and 10.]

[74] Hashem M. Pesaran & Yongcheol Shin (1999), "An autoregressive distributed-lag modelling approach to cointegration analysis", In: Steinar Strøm (Ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, pp. 371–413, Cambridge University Press. [Cited on page 3.]

[75] Hashem M. Pesaran, Yongcheol Shin & Richard J. Smith (2001), "Bounds testing approaches to the analysis of level relationships", *Journal of Applied Econometrics*, **16**, 289–326. [Cited on pages 3 and 4.]

[76] Peter C. B. Phillips & Pierre Perron (1988), "Testing for a unit root in time series regression", *Biometrika*, **75**(2), 335–346. [Cited on page 5.]

[77] Burçak Polat (2018), "The influence of FDI on energy consumption in developing and developed countries: A dynamic panel data approach", *Journal of Yasar University*, **13**(49), 33–42. [Cited on page 11.]

[78] Présidence de la République de Madagascar, *La Politique Générale de l'État 2019–2023*. Retrieved February 14, 2024, from `https://www.diplomatie.gov.mg/images/ppd/iem-pge-2019-au-2023-vf.pdf` [Cited on page 2.]

[79] Présidence de la République de Madagascar, "Déclaration Nationale durant le segment de haut niveau, 09 Decembre 2023, Dubaï, Emirats Arabes Unis" (December 09, 2023). Retrieved February 10, 2024, from `https://unfccc.int/sites/default/files/resource/MADAGASCAR_cop28cmp18cma5_HLS_FR.pdf` [Cited on page 1.]

[80] Présidence de la République de Madagascar (2024), *La Politique Générale de l'État 2024-2029*. [Cited on pages 2, 11, and 12.]

[81] PRC-ELEC – Programme de Révision du Cadre juridique du secteur Electricité, appuyé par la Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2019), *Guide sur les avantages fiscaux en faveur des énergies renouvelables*, Ministère de l'Eau, de l'Énergie et des Hydrocarbures (MEEH), Office de Régulation de l'Électricité (ORE), Agence de Développement de l'Électrification Rurale (ADER), Madagascar. [Cited on page 13.]

[82] Rakotoarimanana Z. M. Harivelo & Rakotoarimanana Z. Harifidy (2022), "A review of environmental protection and sustainable development in Madagascar", *J – Multidisciplinary Scientific Journal*, **5**(4), 512–531. [Cited on page 1.]

[83] Franck M. Ramaharo (2024), "ARDL Bounds testing approach for assessing the macroeconomic determinants of renewable energy consumption in Madagascar", *Open Science Framework*, Center for Open Science. [Cited on page 3.]

[84] Franck M. Ramaharo & Fitiavana M. Randriamifidy (2023), "Determinants of renewable energy consumption in Madagascar: Evidence from feature selection algorithms", *Social Science Open Access Repository (SSOAR)*, **90206**, Leibniz Institute for the Social Sciences, Germany. [Cited on pages 2, 12, and 13.]

[85] Mamy N. R. Randrianarivelo, Rijalalaina Rakotosaona, Edouard R. Andrianarison (2022), "Changement climatique et transition énergétique: Quel avenir pour Madagascar?, *International Journal of Progressive Sciences and Technologies*, **34**(2), 295–308. [Cited on page 2.]

[86] Repoblikan'i Madagasikara, "Loi n°2017-020 du 22 novembre 2017 portant Code de l'Électricité à Madagascar". Retrieved December 15, 2023, from `https://www.fao.org/faolex/results/details/fr/c/LEX-FAOC173232/` [Cited on page 9.]

[87] Hannah Ritchie, Pablo Rosado & Max Roser (2023), "CO2 and Greenhouse Gas Emissions", Our World in Data. Retrieved August 01, 2023, from `https://ourworldindata.org/co2-and-greenhouse-gas-emissions` [Cited on page 3.]

[88] Ahmed Samour, M. Mine Baskaya & Turgut Tursoy (2022), "The impact of financial development and FDI on renewable energy in the UAE: A path towards sustainable development", *Sustainability*, **14**, 1–14. [Cited on page 2.]

[89] SDG7 Technical Advisory Group (2021), *Leveraging Energy Action for Advancing the Sustainable Development Goals: Policy Briefs in Support of the High-Level Political Forum*, United Nations Department of Economic and Social Affairs (UN DESA), New York, USA. [Cited on page 1.]

[90] Muhammad H. Shah, Irfan Ullah, Sultan Salem, Sara Ashfaq, Alam Rehman, Muhammad Zeeshan & Zeeshan Fareed (2022), "Exchange rate dynamics, energy consumption, and sustainable environment in Pakistan: new evidence from nonlinear ARDL cointegration", *Frontiers in Environmental Science*, **9**, 1–11. [Cited on page 10.]

[91] Muhammad Shahbaz, Betül A. Topcu, Sevgi S. Sarigül & Xuan V. Vo (2021), "The effect of financial development on renewable energy demand: The case of developing countries", *Renewable Energy*, **178**, 1370–1380. [Cited on page 10.]

[92] Patrícia Pereira da Silva, Pedro A. Cerqueira & Wojolomi Ogbe (2018), "Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL", *Energy*, **156**, 45–54. [Cited on page 8.]

[93] SEforALL – Sustainable Energy for All, "Taking the pulse of energy access in Madagascar", In: *Energizing Finance: Taking the Pulse 2019 - Madagascar, the Philippines and Uganda*, Sustainable Energy for All. [Cited on page 12.]

[94] SOLIDIS (2017), "Tourisme durable et énergie renouvelable: solidis a contribué à la journée thématique", *Lettre d'information* **16**, 2–3. [Cited on page 12.]

[95] Zhongye Sun, Xin Zhang & Yifei Gao (2022), "The impact of financial development on renewable energy consumption: A multidimensional analysis based on global panel data", *International Journal of Environmental Research and Public Health*, **20**(4), 1–20. [Cited on page 2.]

[96] Dinesh Surroop & Pravesh Raghoo (2018), "Renewable energy to improve energy situation in African island states", *Renewable and Sustainable Energy Reviews*, **88**, 176–183. [Cited on page 10.]

[97] SUNREF – Sustainable Use of Natural Resources and Energy Finance, "Sunref Madagascar: SUNREF Madagascar est un trait d'union entre tous les acteurs". Retrieved October 15, 2023, from `https://sunref.solidis.org/sunref-madagascar/` [Cited on pages 2 and 10.]

[98] Jean Marie Takouleu, "Madagascar: des appels d'offres pour 210MW d'énergie solaire à Ihazolava et Mahajanga", *Afrik21* (July 17, 2023). Retrieved October 1, 2023, from `https://www.afrik21.africa/madagascar-des-appels-doffres-pour-210mw-denergie-solaire-a-ihazolava-et-mahajanga/` [Cited on page 8.]

[99] Xavier Takam Tiamgne, Felix K. Kalaba & Vincent R. Nyirenda (2022), "Mining and socio-ecological systems: A systematic review of Sub-Saharan Africa", *Resources Policy*, **78**, 1–19. [Cited on page 13.]

[100] Emiliano Tossou, "Rio Tinto va consacrer 7.5 milliards $ jusqu'en 2030, à la réduction de son empreinte carbone", *Agence Ecofin* (October 22, 2021). Retrieved October 1, 2023, from `https://www.agenceecofin.com/mines/2210-92579-rio-tinto-va-consacrer-7-5-milliards-jusqu-en-2030-a-la-reduction-de-son-empreinte-carbone` [Cited on page 11.]

[101] UNFCCC – United Nations Framework Convention on Climate Change, "L'accord de la COP28 marque le 'début de la fin' de l'ère des combustibles fossiles" (December 13, 2023). Retrieved January17, 2024, from `https://unfccc.int/fr/news/l-accord-de-la-cop28-marque-le-debut-de-la-fin-de-l-ere-des-combustibles-fossiles` [Cited on page 1.]

[102] Zhaohua Wang, Zahoor Ahmed, Bin Zhang & Bo Wang (2019), "The nexus between urbanization, road infrastructure, and transport energy demand: empirical evidence from Pakistan", *Environmental Science and Pollution Research*, **26**, 34884–34895. [Cited on page 13.]

[103] Sarah R. Weiskopf, Janet A. Cushing, Toni L. Morelli & Bonnie J. E. Myers (2021), "Climate change risks and adaptation options for Madagascar", *Ecology and Society*, **26**(4), 1–35. [Cited on page 1.]

[104] World Bank, "Renewable energy consumption (% of total final energy consumption) - Madagascar". Retrieved August 20, 2023, from `https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS?locations=MG` [Cited on page 3.]

[105] World Bank, "Rural population (% of total population) - Madagascar". Retrieved February 14, 2024, from `https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=MG` [Cited on page 10.]

[106] World Bank, "Urban population - Madagascar". Retrieved August 20, 2023, from `https://data.worldbank.org/indicator/SP.URB.TOTL?locations=MG` [Cited on page 3.]

[107] World Bank, "The force of the sun: Madagascar embarks on renewable energy production" (October 10, 2018). Retrieved October 17, 2023, from `https://www.worldbank.org/en/news/feature/2018/10/10/the-force-of-the-sun-madagascar-embarks-on-renewable-energy-production` [Cited on page 8.]

[108] World Bank, "Madagascar set to expand access to renewable energy and digital services thanks to $400 Million credit" (April 7, 2023). Retrieved October 17, 2023, from `https://www.worldbank.org/en/news/press-release/2023/04/07/madagascar-afe-set-to-expand-access-to-renewable-energy-and-digital-services-thanks-to-400-million-credit` [Cited on pages 2 and 10.]

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