Final Project of Stata

TOPIC : IMPACT OF ELECTRICITY CONSUMPTION ON OVERALL AND SECTORAL PRODUCTION AND DETERMINANTS OF AGGREGATE ELECTRICITY DEMAND IN BENIN

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Date: February 2020

Abstract

This paper analyses the impact of electricity consumption on production on the one hand and the determinants of aggregate electricity demand on the other hand. The results show that it is economic growth and the value added of services that cause electricity consumption in the Granger sense. The consumption of electricity itself leads to industrial added value, which proves that there is an energy-dependent economic dynamic in the industrial sector. Moreover, this study shows that the rate of urbanization and the share of industry in GDP are determinants of the aggregate demand for electricity in Benin.

Key words: Electricity demand, Economic growth of Benin, Granger causality test.

Introduction

Electricity is an essential factor in the development of any economy. Whether it is for industrial activities, particularly to operate machinery, transport, access to communication technologies, or the provision of essential services such as education and health, the continuous availability of electrical energy is essential for the smooth running of these sectors. Thus, energy in general, and particularly electric energy, contributes to changes in society and to the improvement of the living conditions of the population. It is for this reason that energy occupies a de facto dominant place in the Sustainable Development Goals (SDGs) to eradicate poverty, protect the planet and guarantee prosperity.

Access to electricity is still a key issue for the African continent, which remains the least electrified. With an average electricity production of 576 kWh per inhabitant (with a low contribution from sub-Saharan Africa excluding South Africa), i.e. only 18.5% of the world average in 2016, Africa is the continent that consumes the least electricity, despite the high demand. Indeed, according to the International Energy Agency (2018), the amount of electrical energy consumed on the continent, 706 TWh, is barely higher than that of Germany: 572.8 TWh. Insufficient production or poor infrastructure quality thus cause power cuts, which are detrimental to production and tarnish the reputation of companies unable to deliver their orders on time. Likewise, the lack of electricity supply discourages potential investors in power-dependent production activities and limits local industrial development. To respond to power outages, some firms then equip themselves with their own generators. By reducing other investment opportunities, power outages also reduce the productivity of firms.

Benin, like other countries in sub-Saharan Africa, is experiencing difficulties in accessing electricity. Only 38% of the population in general has access to electricity, but specifically there are 58% of the urban population with access to electricity and 10% in rural areas. According to Sinsin (2017) national production capacities have changed very little. Between 1990 and 2013, they increased from 32.5 MW installed capacity to about 138 MW, an annual average increase of 5.95%, while peak demand for electricity increased to an average of 8.44% per year. The ever-increasing demand for energy is only met through imports, which account for at least 90% of electricity consumption, reflecting Benin's very high dependence on external sources, particularly the West African Power Pool (an infrastructure connecting the electricity systems of Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, Burkina Faso and Niger).

In addition to this dependence, there are recurrent load shedding incidents that affect all consumers. Various studies (DGAE, 2009; MCC, 2014; INSAE, 2015) have shown that the deficit and discontinuity of energy supply lead to losses of 3 to 5% of GDP. In other words, the shortfall due to the absence of continuous consumption of electric energy generates a significant loss in the value of GDP.

In view of these observations, it is necessary to question on the one hand the impact of electricity consumption on global and sectoral productions and on the other hand also the determinants of electricity demand which is increasingly strong.

This study has two main objectives, namely:

- To determine the causality between electricity consumption and GDP, and to identify the sectors of activity that are linked to electricity consumption;
- To identify the factors that explain the demand for electrical energy.

1. Data

Regarding the first objective of this study, the variables we use real GDP, Agriculture Value Added, Industrial Value Added, Services Value Added which are data extracted from the WDI-Database and are in constant 2010 US$. We also use electricity consumption expressed in kWH, which is taken from the database of the Central Bank of West African States (BCEAO). All these variables cover the period from 1980 to 2017.

Moreover, in the economic literature, the demand for electricity is explained by economic, demographic and social factors. Thus, according to Khanna and Rao (2009), several studies have sought to quantify how aggregate electricity demand responds to income, electricity price and other determinants of electricity demand using national or sectoral data on electricity consumption, real GDP, real electricity price, temperature measures, urbanization rate, stock or prices of appliances, prices of other forms of energy, and lagged values of electricity consumption.

In accordance with our second objective, we will then explain electric power demand by the share of urban population, real GDP, the share of renewables in electricity generation, and the share of industry in GDP (the latter three variables are derived from the WDI-Database). These data cover the period from 1990 to 2015. Since we do not have data on the prices at which electricity is sold to consumers over the entire period, our estimate may be tainted by an omission bias. This will be discussed further below.

Descriptive statistics

Table 1: Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
GDP	38	4.91 e+09	2.19 e+09	2.21 e+09	9.64 e+09
Agriculture value added	38	1.07 e+09	5.02 e+08	3.91 e+08	2.03 e+09
Industry value added	38	1.31 e+09	4.03 e+08	5.49 e+08	2.26 e+09
Services value added	38	2.08 e+09	1.08 e+09	9.86 e+08	4.50 e+09
Electric power consumption (kWH)	38	422406.7	295872.4	97615	959220
Industry value added share in the GDP	38	18.87084	6.125491	11.98263	29.72464
urbanization rate (%)	38	37.69932	5.466411	27.339	46.768
Renewable electricity output percentage	26	1.324297	1.498649	0	5.555556

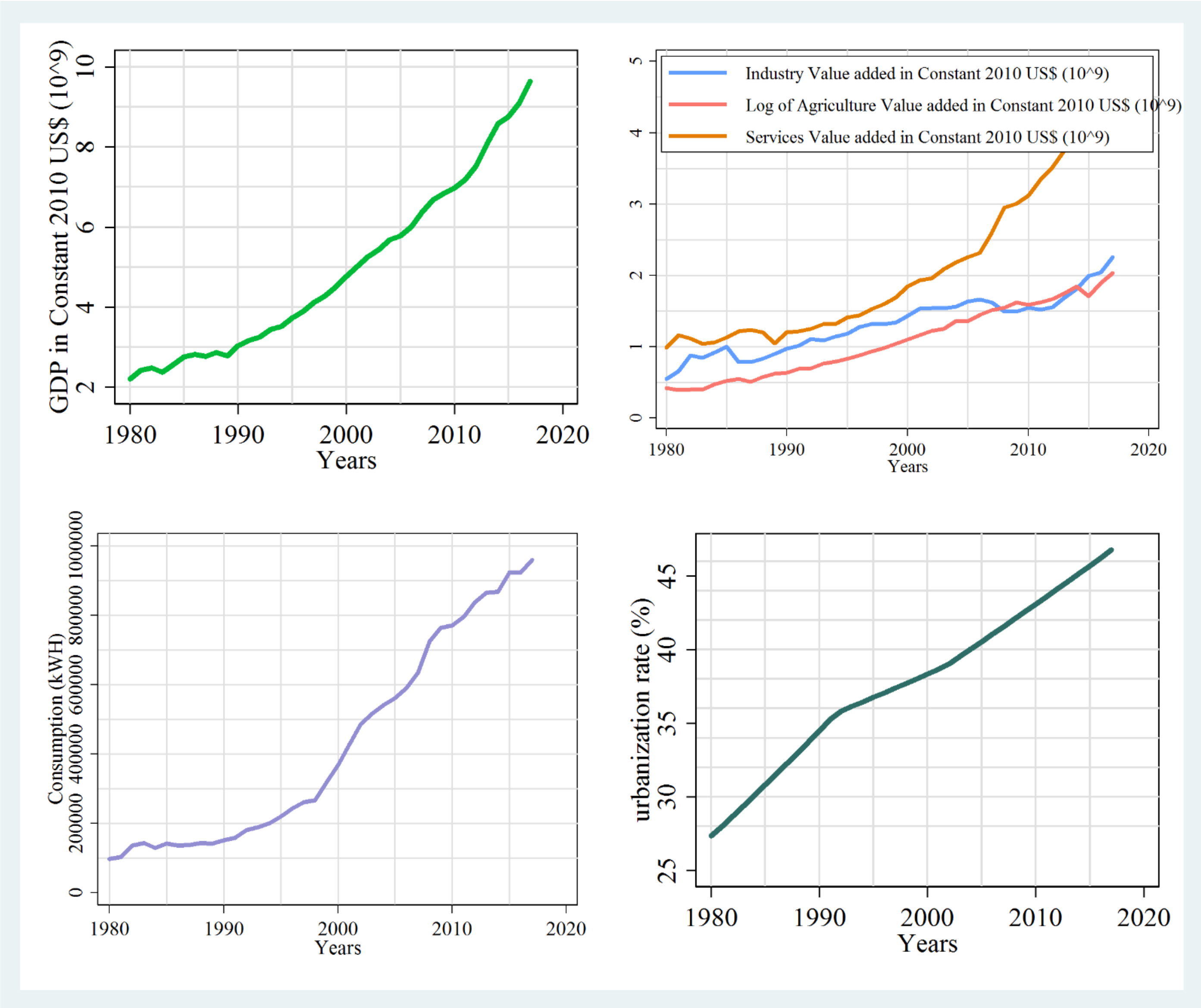
Table 1 presents descriptive statistics for the variables in this study. It shows that the average electricity consumption in Benin is 422 406.7 kWH and the highest level is 959 220 kWH which represents 0.000149% of the Mondial production. Similarly, the average of Renewable electricity output percentage is less than 2 percent. Also, the urbanization rate almost doubled over the period. It rose from about 27% to 47%. This increase characterizes the strong demographic pressure as well as the rural exodus.

The graph below shows the evolution of GDP, sectoral value added, electricity consumption and the rate of urbanisation between 1980 and 2017 in Benin. GDP and agricultural and service production increased overall between 1980 and 2014. This evolution shows two important moments. From 1980 to 1990, national and sectoral production was in an unstable trend: it alternated between declining and increasing. This situation could be explained by the political instability that prevailed during this period. From 1991 to 2017, there was an upturn in economic activity, with an overall upward trend maintained. Industrial value added experienced weak growth over the study period. The position of the value added curve in services vis-à-vis that of agricultural and industrial value added shows that it contributes most to national wealth. From 2007 to 2014, agricultural and industrial value added seems to contribute in the same proportions to national wealth.

Between 1980 and 2017, per capita electricity consumption shows an overall upward trend. After 1998, there is a rapid increase in per capita electricity consumption. This would be explained by the measures taken by governments to alleviate the 1997 energy crisis, including the construction of a 25 MW thermal power plant in 1997. Towards 2007 we note a rebound in electricity consumption, this is certainly due to an increase in supply thanks to the construction of an 80 MW dual power plant.

As for the rate of urbanization, we note that it has an increasing evolution throughout the period with a stronger growth between 1980 and 1992 approximately.

Graph 1: Evolution of GDP, sectoral value added, electricity consumption and urbanisation rate between 1980 and 2017



2. Methodology of empirical analysis

According to Wehbe et al (2018), there are two main approaches to analyze the causal link between economic growth and electricity consumption: the multivariate approach and the bivariate approach. In the multivariate approach, several authors specify a production function in which GDP is explained by electricity consumption, capital, labour and technological change. In this approach, the VECM (preceded by a Johansen test) and ARDL models are generally used to study cointegration (the existence of a long-run relationship between two or more time series) between GDP and electricity consumption, and then a Granger or Toda Yamamoto causality test is used to study causality. In the bivariate approach only GDP and electricity consumption are used as variables in the model. In this case the study of cointegration can be done using the Engle-Granger method. In our analysis, in order to simplify matters, we will adopt a bivariate approach by limiting ourselves to two variables: we will study the causality between electricity consumption and GDP, and the causality between electricity consumption and the value added of each sector of the economy. To do so, we will carry out the Dickey-Fuller Augmented and Philips-Perron stationarity test. Then we will use Engle and Granger's method to test the presence of cointegrating relations between the pairs of series. If there is a cointegrating relationship, we estimate an error-correction model to account for short-term fluctuations and look for the direction of causality. In the absence of cointegration, however, we look directly for causality using a Granger causality test.

- **Cointegration test of Engle and Granger**

The equation to be estimated to test cointegration between two similar integrated variables is:

$$Y_t = \alpha_0 + \alpha_1 E_t + \varepsilon_t \quad (1)$$

Where Y_t denotes either GDP or value added of agriculture, value added of industry, value added of services, E_t represents the consumption and ε_t represents the error term. It is the stationarity of the residual of this model that will be tested to judge cointegration.

In case of cointegration, the error-correction model is estimated:

$$\Delta Y_t = \beta_1 + \beta_2 \Delta E_t + \gamma e_{t-1} \quad (2)$$

Where e_{t-1} is the lagged residual of the first equation, and γ must be negative to account for a restoring force to long-term equilibrium.

- **Causality test**

Causality tests in the sense of Granger or Toda-Yamamoto (indeed, in the presence of cointegration, the causality analysis according to the Granger approach is no longer valid as shown by Phillips and Toda (1993)) will be carried out using the VAR model.

Consider two stationary variables y_{1t} and y_{2t} and a VAR(p) representation of the two variables:

$$\begin{cases} y_{1t} = \delta_1 + \sum_{i=1}^{p} \alpha_{1i}\, y_{1t-i} + \sum_{i=1}^{p} \beta_{1i}\, y_{2t-i} + \vartheta_{1t} \\ y_{2t} = \delta_2 + \sum_{i=1}^{p} \alpha_{2i}\, y_{1t-i} + \sum_{i=1}^{p} \beta_{2i}\, y_{2t-i} + \vartheta_{2t} \end{cases}$$

- ✓ y_{2t} does not cause y_{1t} if hypothesis $H_0 : \beta_{11} = \beta_{12} = \cdots = \beta_{1p} = 0$ is not rejected.
- ✓ y_{1t} does not cause y_{2t} if hypothesis $H_0 : \alpha_{21} = \alpha_{22} = \cdots = \alpha_{2p} = 0$ is not rejected.

The variable y_{2t} causes the variable y_{1t} in the Granger sense if the predictability of $y_{1t}$is improved when the information about y_{2t} is incorporated into the analysis.

- **Determinants of Aggregate Electricity Demand**

To identify the determinants of electricity demand, we will estimate the following model:

$$demand_t = \theta_0 + \theta_1 urban_t + \theta_2 industryshare_t + \theta_3 renewableshare_t + \theta_4 gdp_t + \varepsilon_t \quad (3)$$

Where $demand_t$ is the demand for electricity represented by consumption, $urban_t$ the share of the urban population, $industryshare_t$ the share of renewables in electricity generation and gdp_t real GDP.

3. Results

<u>Table 2:</u> Coefficient of correlation between electricity consumption and the different productions

	GDP	Agriculture	Industry	Services
Electricity consumption	0.9903 ***	0.9777 ***	0.9362 ***	0.9730 ***

*** indicates significance at the 1% threshold

According to this table, GDP and sectoral value added are highly correlated with consumption.
of electric power.

Explanatory analysis

The implementation of the different stationarity tests for each series leads to the results summarised in Table 3 below:

Table 3: Results of stationarity tests

	ADF test		PP test		Conclusion
	In level	First difference	In level	First difference	
log(GDP_t)	8.573	- 3,090***	11.685	-3.048***	I(1)
log($AGRI_t$)	-3.992***		6.562	-8.418***	I(1)
log($INDUS_t$)	2.564	-4.692***	-3.695**		I(1)
log($SERV_t$)	4.653	-4.631***	5.450	-4.747***	I(1)
log($ELEC_t$)	5.592	-3.275***	4.953	-3.208***	I(1)

*** significance at the 1% threshold; ** significance at the 5% threshold; log : logarithm

The result of the stationarity test of the different variables shows that the series log(GDP_t), log($SERV_t$) and log($ELEC_t$) are integrated of order 1 according to the Augmented Fuller Dickey and Phillips-Perron tests. However, the results of the two tests differ for séries log($AGRI_t$) et log($INDUS_t$) series. In this case, the KPSS test is performed to decide. The KPSS test concludes in favour of the presence of a unit root for both series. In the end, all these series are integrated of order 1.

Being integrated of the same order, all these series are likely to be cointegrated. By definition, two series X_t and Y_t whose processes are integrated of order 1 are said to be cointegrated, if there is a unique linear combination of the two variables which turns out to be integrated of order 0, i.e. which is stationary. These two series will therefore tend to vary together over time. The approach used in this work to test the cointegration between electricity consumption, GDP, and sectoral value added in Benin between 1980 and 2017 is Engle and Granger's two-step methodology. The following table presents the stationarity test of model residuals between electricity consumption and GDP and then between consumption and each sectoral value added.

Table 4 ADF test for residuals

	ADF test	
	In level	Engle-Yoo stat
e $_{\text{PIB-ELEC}}$	-1.697	-3.67
e $_{\text{AGRI-ELEC}}$	-2.076	-3.67
e $_{\text{INDUS-ELEC}}$	-3.166	-3.67
e $_{\text{SERV-ELEC}}$	-1.473	-3.29

In this table for example, e $_{\text{PIB-ELEC}}$ is the residual of equation 1 estimated between gdp and electricity consumption, Based on the tests performed, we find that the residuals are not stationary (the statistics from the stationarity test are higher than the statistic tabulated by Engle- Yoo)). Therefore, we did not find a long-term relationship between electricity consumption, growth and the different sectors of the economy. Therefore, the relationship between the variables is a short-term one, which we will detect by the bivariate VAR model with the variables in first difference. The order of the VAR model is determined by the number of lags that minimizes the AIC, BIC, HQIC criteria.

Table 5: VAR(1) between D(log(GDP) and D(log(ELEC) and Granger causlity test

	D(log(GDP$_t$)	D(log(ELEC$_t$))
D(log(GDP$_{t-1}$))	-0,072	1.041***
D(log(ELEC$_{t-1}$))	-0.106*	0.069
C	-0.048***	0.017 ***
R^2 ajusté	0.0793	0.2094
P>chi2	0.2120	0.0085

Null hypothèses	Khi-sq	Prob	Conclusion
D(log(GDP$_t$)) doesn't cause **D(log(ELEC$_t$))**	8.8784	0.003	Rejection of H0 at the 5 %
D(log(ELEC$_t$)) doesn't cause **D(log(GDP$_t$))**	2.6604	0.103	Acceptance of H0 at the 5%

The GDP of year t is significantly and negatively influenced by last year's electricity consumption. This is still quite surprising, as we know that the two series are positively correlated; the R^2 of the GDP equation is not very interesting.

On the other hand, we note that GDP growth has a very significant impact on electricity consumption. Indeed, a 1% increase in GDP growth leads to a 1,041% increase in electricity consumption the following year. Thus, it is economic growth that causes electricity consumption in the sense of Granger.

- **Link between agricultural value added and electrical energy consumption**

Table 6 : VAR(1) between D(log(AGRI) and D(log(ELEC)) and Granger causality test

	D(log(AGRI$_t$))	D(log(ELEC$_t$))
D(log(AGRI$_{t-1}$)	-0.181	0.057
D(log(ELEC$_{t-1}$))	-0.005	0.112
C	-0.053***	0.057 ***
R^2 ajusté	0.0378	0.0164
P>chi2	0.4930	0.7412

Null hypothèses	Khi-sq	Prob	Conclusion
D(log(AGRI$_t$)) doesn't cause **D(log(ELEC$_t$))**	0.0719	0.789	Acceptance of H0 at the 5 %
D(log(ELEC$_t$)) doesn't cause **D(log(AGRI$_t$))**	0.0022	0.962	Acceptance of H0 at the 5%

In the model between the consumption of electrical energy and agricultural value added, there are no significant coefficients except for the constants: therefore, the consumption of electrical energy does not have a significant effect on agricultural value added. This result is justified by the fact that the agricultural sector in Benin is not a major consumer of electrical energy. Indeed, the agricultural sector is the preserve of rudimentary techniques and practices with low electricity use.

The lack of significant causality between the agricultural sector and electricity consumption suggests that Benin's agricultural sector and electricity consumption are not significantly dependent on each other. Benin's agricultural production is still in a state of rent, especially cotton rent.

- **Link between industry value added and electrical energy consumption**

Table 7 : VAR(1) between D(log($INDUS_t$)) and D(log(ELEC) and Granger causality test

	D(log($INDUS_t$))	D(log($ELEC_t$
D(log($INDUS_{t-1}$))	0.285*	0.178
D(log($ELEC_{t-1}$))	-0.457*	0.030
C	-0.052***	0.053 ***
R^2 ajusté	0.1462	0.0511
P>chi2	0.0458	0.3791

Null hypothèses	Khi-sq	Prob	Conclusion
D(log($INDUS_t$)) doesn't cause **D(log($ELEC_t$))**	1.3934	0.238	Acceptance of H0 at the 5 %
D(log($ELEC_t$)) doesn't cause **D(log($INDUS_t$))**	5.4847	0.0019	Rejection of H0 at the 5%

The amount of electrical energy consumed in year t has a negative impact on industrial value added one year later.
We note a lack of a significant relationship between the current value of electricity consumption and industrial value added. This would be justified by the embryonic state of Beninese industry. Indeed, Benin does not have a developed industrial sector capable of boosting economic growth.
The Granger causality test indicates a unidirectional causality between industrial added value and electricity consumption: it is electricity consumption that drives industrial added value and therefore there is a dependent economic dynamic.
energy in the industrial sector.

- **Link between services value added and electrical energy consumption**

Table 8 : VAR(1) between D(log(SERV) and D(log(ELEC) and Granger causality test

	D(log(($SERV_t$))	D(log($ELEC_t$)
D(log(($SERV_{t-1}$))	-0,001	0.484***
D(log($ELEC_{t-1}$))	-0.117	0.095
C	-0.045***	0.036 ***
R^2 ajusté	0.0244	0.1702
P>chi2	0.6370	0.0249

Null hypothèses	Khi-sq	Prob	Conclusion
D(log(($SERV_t$)) doesn't cause **D(log($ELEC_t$))**	6.758	0.009	Rejection of H0 at the 5 %
D(log($ELEC_t$)) doesn't cause **D(log(($SERV_t$))**	0.8976	0.343	Acceptance of H0 at the 5%

The VAR model shows that the consumption of electrical energy does not have a significant effect on the value added of services. This result could be justified by the dominance of trade and transport in this sector. These two industries are practically no consumers of electricity in Benin. On the other hand, the value added of services has an impact on electricity consumption.
The Granger causality test indicates a unidirectional causality between the value added of services and electricity consumption: it is the value added of services that drives electricity consumption. As the service sector grows, there is a greater need for equipment that consumes more electricity in order to expand trade, for example.

- **Determinants of demand**

The estimation of equation 3 leads to the following result:

Table 9 : Result of estimation for determinants of agregate electricity demand

Demand = lnconso_elec	**coef**	**t**	**P>|t|**
Explanatory variables			
urban_rate (%)	0.0255976	2.01	0.058
Industry_va_gdp(%)	0.0075426	3.67	0.001
Renewable	0.0037685	0.73	0.474
lnconso_elec (-1)	0.7936251	10.47	0.000
constant	1.550867	3.42	0.003
R^2 = 0,99			
F(4, 21) = 2025.27	Prob > F = 0.00		

In this model, the variable GDP was left out of equation 3, contrary to what is specified in equation 3, due to multicollinearity problems. In addition, a lagged term for the dependent variable was introduced to correct for the autocorrelation of the residuals, since the Cochrane-Orcutt correction was not successful. The residuals are homoscedastic. The model has a satisfactory explanatory power (it explains 99% of the variations in demand) with an average forecast error of the order of 3. 42%, and is globally significant. These estimates show that a 1% increase in urban population leads to a 2.5% increase in electricity demand; which is logical but may be underestimated as more than 58% of Benin's urban population is connected and more than 60% of energy demand is absorbed by the residential sector (Sinsin, 2017). In addition, the rural exodus accentuates the demand for electricity. The share of industry is a key variable in energy demand, as is the urban population. Indeed, the coefficient of the variable is significant and positive, which shows a high interest for governments to strengthen the industrialization of the country while making electricity available for their activity. According to the results of our model, we find that a 1% change in industry's share of GDP induces a 0.7% growth in electricity demand. The share of renewables in electricity generation does not influence the level of demand. This can be understood by the fact that in Benin, like most developing countries, the use of renewable energies, particularly solar energy, is much higher at the disaggregated level of economic agents.

- **Possibles endogeneity bias**

As discussed above in terms of data presentation; the absence of price in the demand model is a significant omission bias. It is therefore possible that some parameters may be over- or underestimated. Furthermore, even if we had used an average electricity price, this leads to yet another endogeneity in the model, due to simultaneity. Indeed, consumers of electricity do not face a single price, but rather a price schedule, with decreasing or increasing block pricing. The marginal price is dependent on the amount of consumption and influences the level of consumption. So, Both the ex post marginal and average prices are determined simultaneously with the level of consumption; and thus, their inclusion as explanatory variables leads to correlation between price and error term of the electricity demand equation. Khanna and Rao (2009) stated that according to Tayor (1975) we can solve partially the problem by including both the marginal price of the last block consumed and the average price as predictors in the demand function, but he recommends using actual values from the price schedules and not ex post values. It is also argued that other variables such as the lagged dependent variable and the GDP if they are included in the as regressors are likely to be endogenous and lead to simultaneity bias. To solve those problems in the literature, studies use cointegration techniques to avoid spurious regressions between variables that may be driven by time trends and to control for endogeneity of the explanatory variables.

Conclusion

Given the importance of electricity in economic activity, this study attempted to identify whether there is a causal link between electricity consumption and Gross Domestic Product on the one hand and the sectors of economic activity that are related to this electricity consumption on the other. The results showed that a 1% increase in GDP growth in year n leads to a 1,041% increase in electricity consumption the following year (n+1). This implies that it is economic growth that causes electricity consumption in the Granger sense. As with economic growth, the added value of services leads to electricity consumption. This means that the more the service sector develops, the more it requires the use of materials or equipment that consume an increasing amount of electricity. On the other hand, it is the consumption of electricity that drives industrial value added, which reflects the existence of an energy-dependent economic dynamic in the industrial sector. And the absence of a link between electricity consumption and agricultural value added reflects the fact that Beninese agriculture is mostly traditional, precarious or even archaic and above all non-mechanized.

Moreover, an analysis of the determinants of the demand for electrical energy shows that the rate of urbanization and the share of industry have a positive influence. This seems logical since the urban population and industry are major consumers of electrical energy. Also, the rural exodus accentuates the need for electricity consumption. The non-influence of the share of renewable energies in electricity production on the level of demand is due to the fact that in Benin, as in developing countries, the use of renewable energies such as solar energy is much greater at the disaggregated level of economic agents. Thus, we can suggest that public authorities should invest more in renewable energy.

The main limitation of this study lies in the fact that the analysis of the determinants of electricity demand does not consider the price of electricity, which could lead to over- or under-estimation of some parameters. Similarly, the inclusion of average electricity prices could have led to another endogeneity issue in the model due to simultaneity. It would therefore be interesting to deepen this study by including other variables that could better explain the demand for electric energy, such as national production capacity and average household income, which could materialize consumer attitudes.

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