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Electricity, Exergy and Economic Growth in Mozambique[1]

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ABSTRACT

Electricity consumption and economic growth attracted the attention of researchers in several countries. Mozambique have few studies on this matter and non-related to useful exergy. This paper analyses the relationship between final electricity consumption, useful exergy and economic growth in Mozambique, from 1971 to 2014. The final electricity consumption data are expressed in GWh, from International Energy Agency database, which for Mozambique (until the date of writing) cover the period from 1971 to 2014. For this analysis an unrestricted VAR models were estimated to capture different types of effects, which are particularly important for an economy that underwent diverse phases and restructuring processes. Results indicate that there was a huge increase in final electricity consumption, from 2000 and 2001. Modelling with final electricity consumption and with useful energy illustrated that economic growth in Mozambique has not been influenced by final electricity consumption and useful exergy. However, economic growth induces final electricity consumption and useful exergy growth. The results suggest that sectors that induce economic growth in Mozambique are the least electricity intensive ones. The Police implications is that electricity access of those sectors that induce economic growth should be enhanced to keep them more competitive, and to sustain the growth.

Keywords: Economic Growth, Electricity Consumption, Energy, Exergy, Mozambique, Useful Exergy
JEL Classifications: C32, O13, O47, Q43

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1. INTRODUCTION

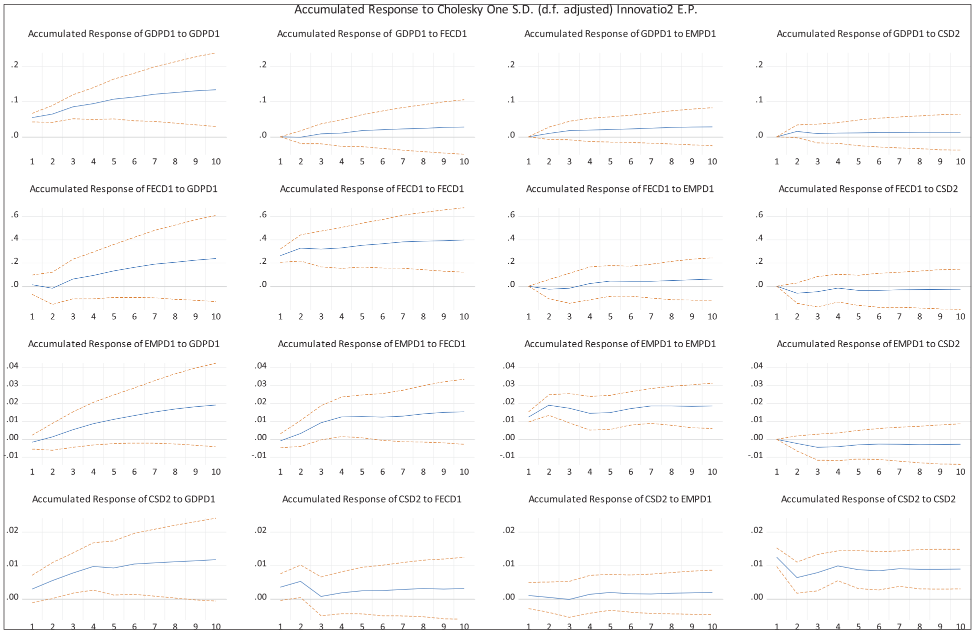
This article analyses the relationship between final electricity consumption (FEC), its useful exergy (UEx) and economic growth in Mozambique, incorporating other relevant variables to the growth of the economy, such as employment and capital stock, from 1971 to 2014. For this analysis, two unrestricted VARs was estimated, as detailed in the methodology.

The relationship between electricity consumption and economic growth has attracted the attention of researchers in several countries. Several studies analyse this relationship. However, the same cannot be said for Mozambique, with few studies on this matter, particularly in a disaggregated way, such as the study of the relationship between electricity across different energy sources and the growth of the economy. This is a field that is deeply unexplored in the context of Mozambique.

Kraft and Kraft (1978) were pioneers in this matter, studying the relationship between energy consumption and the Gross National Product (GNP) of the USA, from 1947 to 1974. The study concluded that there is unidirectional causality from GNP to energy consumption. This finding indicated that the level of economic activity influences energy consumption. However, the level of energy consumption did not influence economic activity in the USA.

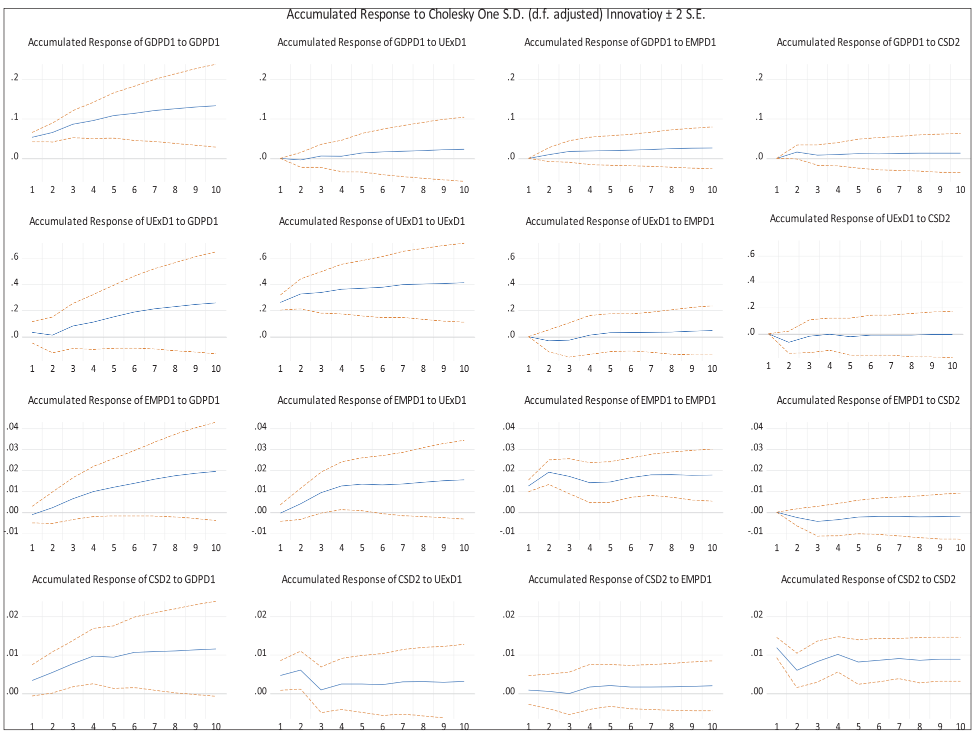
From the various studies carried out on the relationship between electricity consumption and economic output, the

Graph 1: Accumulated impulse response analysis



Source: Author

Graph 2: Accumulated impulse response analysis

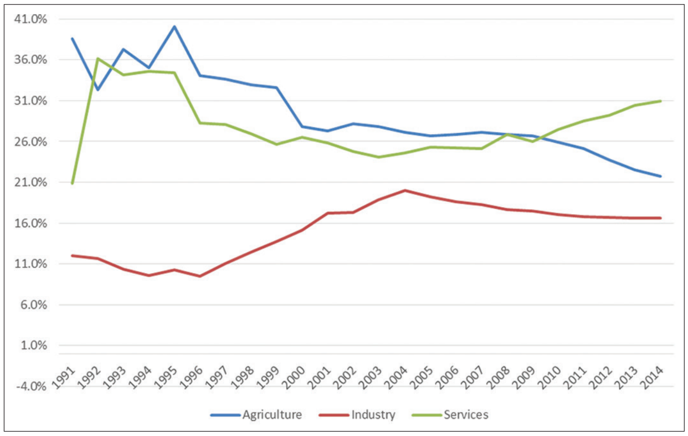


Source: Author

following can be mentioned, as they pertain to African economies.

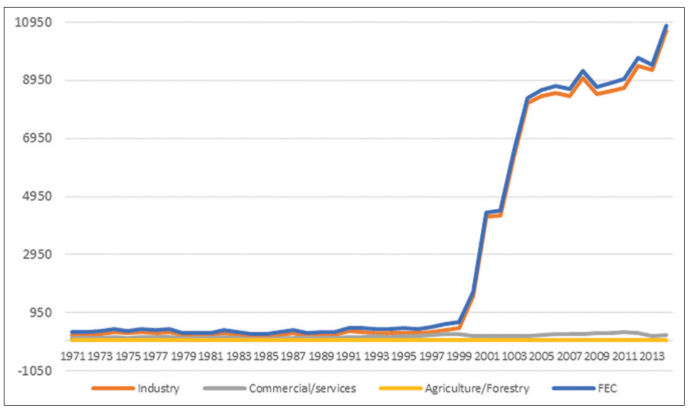
Solarin and Shahbaz (2013), on Angola, concluded that there is a bidirectional causality between electricity consumption and economic growth, meaning that Angola is a country of energy dependence. Despite this result, Angola is not necessarily an industrialized country. Conversely, for South Africa, one of the most industrialized countries in Africa, Khobai's (2018) in a study on the BRICS, concluded that, like other BRICS countries, South Africa is less dependent on electricity consumption, given that electricity does not induce GDP, but GDP induces growth in electricity consumption. These findings suggest that the relationship between GDP and electricity consumption may depend on factors other than the industrialization level. For example, technological advancement of the existing production processes may lead to greater production efficiency, reducing total electricity consumption. The study of the impact of technological

Graph 3: GDP structure at constant prices, percentage (in Meticais 2009)



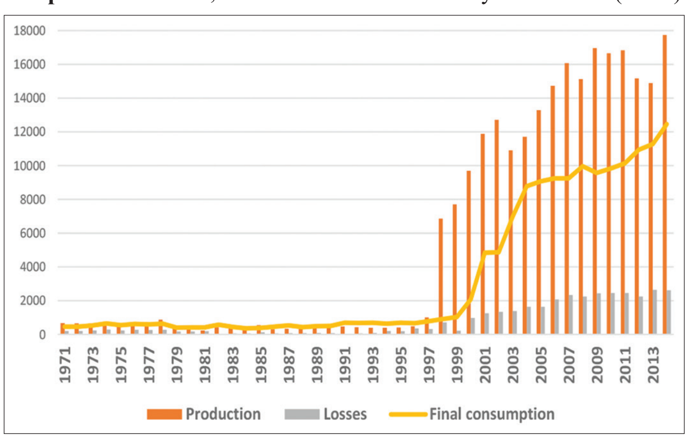
Source: Author (based on INE data - GDP in terms of production)

Graph 4: Final electricity consumption, by economic sector (GWh)



Source: Author (based on data from the IEA Database)

Graph 5: Production, FEC and losses in electricity distribution (GWh)



Source: Author (based on data from the IEA Database)

innovation on the relationship between GDP and electricity consumption is an important topic, even if it is not directly addressed in this article.

Chingoiro and Mbulawa (2017) conducted a study on Botswana, concluding that there is a positive long-term relationship between economic growth and electricity consumption, and that electricity consumption induces long-term economic growth. This result contradicts the study by Yakubu and Jelilov (2017) on the same country, which concluded that the hypothesis of neutrality between electricity consumption and economic growth was to be confirmed, with data from 1990 to 2012. These differences indicate that further studies on this matter are necessary. The divergence of results may occur due to methodological differences and/or to different type of data.

Bah and Azam (2017) explored the causal relationship between electricity consumption, economic growth, financial development and CO_2 emissions in South Africa, and concluded that there is no causality, confirming the neutrality hypothesis. Contrary to other studies based on bivariate or trivial analysis, these authors were based on a multivariate approach, with more than three combined variables, overcoming some bias resulting from bivariate studies, as the latter do not take into account other variables that influence this relationship. These authors argue that an energy saving policy would not have a negative effect on the growth of the South African economy. This result is in line with the conclusion of Yakubu and Jelilov (2017) on South Africa, which also confirmed the neutrality hypothesis.

Appiah (2018), when analysing the causality between energy consumption and the growth of the economy and CO_2 emissions in Ghana, concluded that there is a causality in both directions (double), in the long run. This result contradicts the result of Yakubu and Jelilov (2017) for the same country, which indicated that there is unidirectional causality from energy consumption to economic growth, confirming the growth hypothesis and not the feedback hypothesis obtained by Appiah (2018).

Salamaliki and Venetis (2013) argue that the different results from the analysis between energy and economic growth should not be surprising because countries have different energy consumption patterns, different energy sources, infrastructures, institutions and policies, in addition to different stages of development. These differences generate variances in the role of energy in the economy across countries and time.

The relationship between electricity consumption and economic growth suggests that the limitation of the analysis should not be solved simply by using a multiplication of variables, since the economic reality is profoundly multifaceted, interwoven and complex. Model specification improvements or the extension of the period of analysis, among other technical aspects, may increase results accuracy. For example, tests such as the “ADF test” fit better on long-term data, which means that they lose their effectiveness when applied to data that does not cover considerably long periods. Another factor to consider is the local context that affect the dynamics of the economy.

The fact that different methodologies are applied and different periods of analysis are considered, as well as data from different data sources, in some cases not mutually consistent, and the analysis focus (aggregated or disaggregated by type of energy source), may also explain differences and contradictions between studies pertaining to the same geographical spaces.

Therefore, this is still a field of study with enormous controversies, requiring additional studies for a better understanding of the relationship between economic growth and energy consumption, in

Table 1: Result of Granger's Causality (in both FEC and UEx models)

Independent Variables	Dependent Variables				
	GDP	**FEC**	**UEx**	**Emp**	**CS**
GDP	Not applied	It is caused by GDP	It is caused by DGP	It is caused by GDP	It is caused by GDP
FEC	It is not caused by FEC	Not applied	Not applied	It is caused by FEC	It is not caused by FEC
UEx	It is not caused by UEx	Not applied	Not applied	It is caused by UEx	It is not caused by UEx
Emp	It is not caused by Emp	It is not caused by Emp	It is not caused by Emp	Not applied	It is not caused by Emp
CS	It is not caused by CS	It is not caused by CS	It is not caused by CS	It is not caused by CS	Not applied
OBS.	GDP is not caused either individually or jointly (it has its own dynamics)	FEC is not caused jointly by other variables	UEx is not caused jointly by other variables	Emp is caused jointly	CS is caused jointly

Source: Author

order to allow the design of energy policies that are more adequate and favourable to economic growth and development.

In the case of Mozambique, Nindi and Odhiambo (2014) studied the energy variable (including all forms of energy) and confirmed the growth hypothesis. In contrast, the result of Mahfoudh and Amar (2015), referring to 19 African countries, including Mozambique, confirmed the conservation hypothesis.

Nindi and Odhiambo (2014) and Bay (2018) came to the conclusion that energy consumption drives economic growth in Mozambique. Both studies analysed the energy consumption variable in its aggregated form (including all forms and energy sources). Sunde (2020) in his study analysed the relationship between energy consumption and economic growth in SADC countries (including Mozambique), from 1971 to 2015. The study concluded that in the case of Mozambique, there is no causality between energy consumption and economic growth. Although the used concept of energy is broader (which means the total consumption of all energy sources), this result suggests that there is no effect of the total consumption to GDP, nor of GDP to energy consumption.

In this article, the objective is to analyse the relationship between energy consumption and economic growth, based on one of the energy forms: electricity, which is a conventional one with greater consumption in the productive process in Mozambique (industrial sector; commercial and services; and, even though to a lesser extent, the agricultural sector).

This article is structured as follows: it starts with the introduction; followed by the VAR models and data; the estimation results; discussion and conclusion.

2. THE VAR MODELS AND DATA

The standard, unrestricted VAR model is presented as follows:

$$X_t = c + \sum_{i=1}^{p} A_i X_{t-i} + \varepsilon_t \quad (1)$$

Where:
X_t is the four endogenous variables vector, so that
$X_t \equiv [\Delta logGDP;\ \Delta logFEC;\ \Delta logEmp;\ \Delta logCS]$, in the "FEC model," and
$X_t \equiv [\Delta logGDP;\ \Delta logUEx;\ \Delta logEmp;\ \Delta logCS]$ in the "UEx model."
c is the intercept vector;
is the (4x4) matrix of autoregressive coefficients of order i;
ε_t is a white noise vector, so that:

$$\varepsilon_t = [\varepsilon_t^{GDP}; \varepsilon_t^{FEC}; \varepsilon_t^{Emp}; \varepsilon_t^{CS}];$$

p is the VAR length, the number of lags to be determined from information criteria;
GDP - represents real gross domestic product, in local currency (Metical), at constant 2009 prices;
FEC indicates final electricity consumption, in GWh;
Emp - represents employment;
CS - is the capital stock in local currency (Metical), at constant 2009 prices.

UEx - data for Mozambique was constructed inspired in the literature (Felício, et. al, 2019; Serrenho et al., 2014; and Ayres et al., 2005) following four steps: the first step was the conversion of FEC into exergy; the second was the allocation of final exergy consumption, per sector, to the different end-uses, the third was the application of the final exergy efficiencies, according to end-uses, to obtain the useful exergy (UEx) data of the FEC, per sectors for Mozambique. Finally, the total UEx by the sum of disaggregates results.

Analysis of the stationarity of the series, based on the Augmented Dickey-Fuller test, indicated that all series under study were non-

2 Constructed data and methods are available from the authors on request.

stationary in levels, which implied their differentiation. In this process, the series were stationary in first differences, with the exception of the capital stock series, which was only stationary in second differences. The number of lags was chosen using the AIC criterion, two lags were chosen.

Data on final electricity consumption are expressed in GWh. These data refer to the annual final consumption of the productive sector of the economy, thus excluding the residential sector. The source is the International Energy Agency (IEA) database and cover the period from 1971 to 2014. The data before 1991 result from IEA estimates, while the data afterwards were systematized in the database of the IEA based on data received from the Ministry of Energy of Mozambique (Statistical Yearbooks), and the African Energy Commission (ESKOM Statistical Yearbooks, with data coming from EDM - Electricidade de Moçambique). (IEA, 2019)

Data on the UEx of the FEC were also constructed, as they did not exist before for Mozambique. For this purpose, the methodology followed in international studies on the subject was applied, based on the methodology of Miller et al. (2016)[2], which postulates the following fundamental steps: first, the conversion of FEC into its exergetic equivalence; second, the association of the exergy data with categories of exergy, based on useful uses; and the third, the determination of UEx based on the application of the efficiencies corresponding to each category of use.

GDP data were obtained from the National Institute of Statistics (NIS) of Mozambique, starting in 1991. Data for the period prior to 1991 were reconstructed.

Data on employment refer to the number of the employed population in millions of inhabitants, and were obtained from the PWT database, version 9.1. These data include all the people involved in productive activities, that is, those who work. (Inklaar and Timmer, 2013).

The data for the capital stock, in "meticais" and at constant prices in 2009, were constructed from investment data, obtained from NIS (starting in 1991), and from the International Monetary Fund (IMF) for previous periods. For this purpose, a constant depreciation rate (geometric depreciation model), as used by IMF was adopted. The construction of capital stock data followed the Permanent Inventory Method (MIP).

3. ESTIMATION RESULTS

The VAR models were estimated using Eviews, version 10. Residuals showed no signs of autocorrelation, as they passed both a Lagrange Multiplier (LM) and a Portmanteau autocorrelation test. Also, they displayed no evidence of nonnormality and of heteroscedasticity.

3.1. Granger Causality

Granger (1969) causality test can generate one of the four results: (i) unidirectional causality from Y to X; (ii) unidirectional causality from X to Y; (iii) bidirectional causality (Y ↔ X); or (iv) absence of causality between Y and X.

Granger's causality test for the four variables, with two lags, places each variable as a dependent variable in relation to the other variables. The null hypothesis under test is that the independent variables do not cause the dependent variable.

The result of this analysis is systematized in the table below, where causality is detected when the no causality test is rejected with a P-value smaller than 5%.

Results show that GDP is not caused by any of the other variables, either individually or jointly. However, GDP causes all other variables.

FEC; UEx and capital stock are only caused by GDP.

As for employment, it is caused by FEC, UEx and GDP.

The result of Granger's causality test suggests that GDP has own dynamics but it increases the consumption of FEC; UEx; employment and investment.

3.2. Impulse Response Analysis

The impulse response results were obtained using the Cholesky decomposition method. Identification of orthogonal shocks by this method implies the so called ordering of variables.

Thus, a specific shock in the first variable affects all variables simultaneously. Conversely, the first variable is only affected at the same time by an orthogonal shock of its own. The last variable, on the other hand, is affected simultaneously by the shocks of all variables, and affects only itself at the same time. Thus, it is said in the Cholesky decomposition that the variables are ordered from the "most exogenous" to the "most endogenous."

The VAR model is ordered as follows: GDP, FEC, Emp, and CS (in modelling with FEC) and GDP, UEx, Emp, and CS (in modelling with UEx). GDP appears first and has an instantaneous effect on all other variables, but does not respond at the same time to any structural disturbances resulting from other variables. This assumption is in line with results obtained from Granger's causality.

To assess results robustness, the order of the variables was changed and it was found that estimated impulse response functions were similar.

Impulse response analysis allows to glimpse complex relationships across variables, as illustrated in the graphs below (Graphs 1 and 2). The blue line represents the accumulated reaction of the variable to the impulse of a standard deviation in another variable, over 10 periods of shock propagation, while the two red lines represent the 95% confidence interval.

In the FEC model, starting with GDP responses, impulses in other variables never have a significant impact, as the 95% interval always contain the zero value.

Significant effects, or close to significant at this stringent level of significance, include only:

- The response of employment to FEC after 2 years
- The immediate positive response of the capital stock (investment) to FEC. It drop to negative response from the 2nd year
- The positive and significant response of CS to GDP
- And the positive reaction of employment to GDP and to FEC, from the 2nd year.

Consider now in what follows impulse responses with the model with useful exergy. Accumulated responses to Cholesky impulses are shown in the Graph 2:

Responses in this model are strikingly similar to the ones found with the previous one.

4. DISCUSSION OF RESULTS

Results show that GDP is not influenced by electricity consumption (either with FEC or UEx). This is understandable as deriving from the Mozambican economic structure. The Graph 3 illustrates the composition of the GDP, in the period from 1991 to 2014:

The data in the graph above indicates that the agricultural sector had the largest share of GDP until 2010. From 2011, the service sector has been making a greater contribution to GDP. The industry sector continues to make a smaller contribution, despite its remarkable growth in the period from 1997 to 2004. The agricultural sector, declining in relative importance from 1996 to 2014, continues to outpace that of industry.

Compared to the industrial sector, the agricultural and services sectors are not major consumers of electricity. The FEC data indicates that total consumption in the service sector is lower than the industrial one (see data on FEC shown in the Graph 4).

The industrial sector is traditionally the one with the highest consumption of electricity, due to its production processes based on mechanized industrial equipment. Growth in industrial consumption is notable since 2000. This leap was due to the contribution of Mozal's electricity consumption, an aluminium smelting megaproject. The too low level of electricity consumption in the agriculture sector reflects the sector's production process, which is still based on poorly mechanized production processes and low use of modern techniques, such as irrigation systems, among others. The sector is still very dependent on family production.

Therefore, the economic sectors that contribute the most to GDP in Mozambique are those that least participate in the total consumption of electricity. This may be the reason why GDP is less influenced by electricity consumption.

Still on the industrial sector, Castelo-Branco (2003) refers that the weight of the added value of the manufacturing industry on GDP has been very low, and, on the other hand, had little changed from 1960 to 2001. He also mentions that in that period industrial growth slowed, with a tendency to stagnate. Therefore, excluding the Mozal effect, the weight of the added value of the manufacturing industry on GDP in 2001 would be identical to that observed in 1961 or 1971.

Mozal and the food and tobacco industry together represent more than 80% of the industrial product in Mozambique. Mozal alone, with the production of aluminium, represents 99% of metallurgical production in Mozambique. (Castelo-Branco, 2003:11). Although the industrial sector remains underdeveloped, this is the sector that, traditionally, consumes more electricity.

Data on the business sector indicate that 92.7% of companies in Mozambique are small, 4.2% medium-sized and 3.1% are to be included in the group of large companies. (CEMPRE, 2014/2015). The business productive sector is mainly made up of small companies, where electricity consumption is less significant. Also according to the Census in reference, 58.8% of the existing production units are from the commercial sector; 28.2% of the services sector; 7.5% of the industrial sector, electricity and water; 4.5% of the construction industry; and 0.9% from the agricultural and fisheries sector. These data indicate that, in terms of dominant productive units, they are mostly from the commercial branch. Although the agricultural sector represents a smaller number of companies, it is the sector that contributed more significantly to GDP until 2010.

An additional explanatory factor has to do with the end of the armed conflict in Mozambique. During the war, which ended in 1992, electricity transformation and transport infrastructures (as well as other economic infrastructures) were destroyed and their maintenance was impossible, which justifies the leap that occurs in total electricity consumption in the post-war period. However, this post-war leap did not result from an economic structure transformation, which could imply greater dependence of GDP on electricity consumption. The Graph 5 illustrates the production, consumption and losses of electricity:

The Graph 5 shows that both production and electricity consumption grew significantly in the post-war period. The growth in electricity production levels started in 1997, reflecting the result of the post-war recovery and reconstruction of electricity production, transformation and transport infrastructures. However, the increase in electricity availability, which started in 1997, was also accompanied by an increase in "losses" in the distribution process. This growing trend of increasing "losses" is the result of the obsolescence of many of the distribution line infrastructures installed in the colonial period.

The absence of finding an immediate effect of the FEC and the corresponding UEx on GDP should be taken with some caution, as it does not mean that the FEC or UEx are not fundamental to GDP growth. As results illustrated, in the medium and long term there is some relevance of FEC on GDP, as indicated by Granger causality tests. On the other hand, account should be taken not only of the direct, immediate effects, but also of indirect effects, generated by the multiplier outcomes of increased electricity consumption.

Although his centred on electricity consumption only, Sunde (2020) results are close to the ones obtained here.

Note that employment is found to be influenced by both FEC and UEx - increases in electricity consumption can lead to increases in employment.

As the sector that contributes the most to GDP does not coincide strongly with the sector that has the largest share in the FEC, contribute to the result of the relationship between GDP and FEC.

The literature related to the relationship between GDP and electricity consumption (or energy, in its aggregate sense) suggests contradictory results, as presented in the literature review. This contradiction may arise not only from methodological differences in econometric analyses, but also to factors such the ones presented above, like participation of different sectors on GDP and on FEC resulting from the economic structure, as well as from the technological level of the productive processes.

On the other hand, the pattern of the relationship between capital stock and employment is important. If this relationship indicates labour-intensive productive processes (lowering the capital ratio per worker), it can lead to less dependence on electricity consumption of the economy. Economies with capital intensive are more susceptible to greater consumption of electricity, in other to feed its highly mechanized and technologically structured production processes, making GDP more dependent on electricity consumption.

Mozambique's economy has most of its economic sectors dependent on labor-intensive use. Capital intensive production is still weak and limited to large projects (megaprojects) such as Mozal. The agricultural sector is also still labor intensive.

Therefore, the existing economic structure associated with the dominant production models, determines the relationship between GDP and electricity consumption. Hence, there is a need for greater and better harmonization between the energy policy, to be adopted, and the desired economic development models, so that the energy policy can serve the interests and purposes of growth and economic development, aiming the sustained growth of GDP in the long term.

5. CONCLUSION

Results suggests that economic growth in Mozambique is not influenced either by FEC or by UEx. However, economic growth induces increases in FEC and UEx. The conservation hypothesis is verified, which indicates a lesser effect of electricity consumption on economic growth. This, however, does not imply that electricity consumption is irrelevant to economic growth. It only suggests that the current growth pattern of the economy has been less dependent on the FEC and UEx. Sectors that most induce economic growth in Mozambique are the least electricity intensive ones.

The industrial sector remains underdeveloped, but it is the sector that consumes the most electricity and, at the same time, the one that contributes the least to GDP in Mozambique, resulting in the weak dependence of economic growth on the FEC and, consequently, on its corresponding UEx.

This conclusion must be viewed with caution, considering not only the direct, immediate effects, but also their indirect effects, generated by the multiplier effect of the increase in electricity consumption. Whether modelling with the FEC or modelling with the UEx, it was found that the FEC as well as the UEx influence employment, which, although it does not significantly influence GDP, is fundamental for its growth, similar to the capital stock, which result proved to be the only variable most likely to slightly influence GDP.

As the sectors that induce economic growth in Mozambique are the least electricity intensive ones, the electricity access of those sectors, that induce economic growth, should be enhanced to keep them more competitive and to sustain the growth.

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