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EFFECT OF NEGATIVE SHOCKS TO ELECTRICITY CONSUMPTION ON NEGATIVE SHOCKS TO ECONOMIC GROWTH IN BENIN

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Abstract

The current study used an asymmetric approach to establish that negative shocks to electricity consumption have caused negative shocks to economic growth in Benin over the period 1971-2014. In so doing, it has ascertained the conclusion of the national policy framework for electricity which stipulated that shortages of electricity have impeded economic growth. Benin has encountered several electricity shortages in the 1980s, 1990s, and 2000s. Although the share of electricity consumption in total energy consumption is very low in the country, electricity consumption remains essential for of economic growth because shortages of electricity cause reduction in economic growth. This result has some important policy implications in terms of electricity security in Benin.

Keywords: Asymmetric Causality, Electricity Consumption, Economic Growth, Electricity Shortages

1 INTRODUCTION

In general, four different hypotheses have been established in the literature on the causal relationship between energy consumption and economic growth (Payne, 2010; Lee, 2006; Apergis and Payne, 2011; Ozturk, 2010; Ewing et al., 2007; Soytas and Sari, 2003; Apergis and Payne 2009a, 2009b; Bowden and Payne, 2009, 2010). The first is the growth hypothesis, which stipulates that causality runs from energy consumption to economic growth. The second is the conservative hypothesis, which stipulates that causality runs from economic growth to energy consumption. The third is the feedback hypothesis, which states that there is bidirectional causality between energy consumption and economic growth. The fourth is the neutrality hypothesis, which stipulates that no causal relationship exists between energy consumption and economic growth. These four hypotheses are largely discussed among the very few studies which have investigated the relationship between economic growth and energy/electricity consumption for Benin. Most of these studies are cross-country analyses. Wolde-Rufael's (2009) study of 17 African countries, using a Vector Autoregressive (VAR) model comprising variables such as growth, energy consumption, capital and labour, established for three of these countries, including Benin, the existence of a causal relationship running from energy consumption to economic growth. He argued that in these three countriesany energy conservation policy would harm economic growth. He suggested that a country like Benin must increase its energy use in terms of quantity and quality for sustainable economic growth. However, Wolde-Ruafel's (2005) study of 19 African countries, using the bound testing and Toda Yamamoto approaches to granger causality in a bivariate framework, established for nine of these countries, including Benin, that there is no causal relationship between energy and growth. This absence of causality can be the result of omitted variables bias related to bivariate models as explained earlier by Lütkepohl (1982) and further by Wolde-Rufael (2009).

Al-mulali and Binti Che Sab (2012) on 30 African countries including Benin established that total primary energy consumption causes economic growth and financial development but with CO_2 pollution in these countries. Rault et al. (2014), using a VAR model on 16 African countries, including Benin, established a causal relationship running from economic growth to energy consumption for Algeria. They established a bidirectional causal relationship between economic growth and energy consumption for Ethiopia, and a positive causal relationship running from energy consumption to economic growth for seven of these countries (Tunisia, Egypt, Kenya, Senegal, Tanzania, DRC and Morocco). They established a negative causal relationship running from energy consumption to economic growth for South Africa, Zambia and Cameroun. They found no causal relationship between economic growth and energy consumption in the case of Benin.

Dogan (2014) established a causal relationship running from energy consumption to economic growth in the case of Kenya. However, he posited that no causality exists between energy consumption and economic growth in the case of Benin, Zimbabwe and Congo. Menegaki and Tugcu (2016) found no evidence of causality between GDP and energy consumption for 42 African countries, including Benin. Ouedraogo (2013) on countries of the Economic Community of West African States (ECOWAS), including Benin, found opposite results: causality from GDP to energy consumption in the short run and causality from energy consumption to GDP in the long run. She also established a causal relationship running from electricity consumption to GDP in the long run. Fatai (2014) investigated the causal relationship between economic growth and energy consumption for 18 sub-Saharan African countries, and established the absence of a causal relationship between energy consumption and economic growth in Central and Western Africa, including Benin, while in Eastern and Southern Africa he established a causal relationship running from energy consumption to economic growth. Zerbo (2017) investigated the relationship between economic growth and energy consumption for 13 sub-Saharan economies, including Benin, and established a long-run relationship between economic growth and energy consumption for eight of these 13 economies. He also established the absence of no causal relationship between energy consumption and economic growth for Benin, Togo, Senegal, Côte d'Ivoire, Congo, Ghana, and South Africa. For Kenya, Gabon and Nigeria, he established a causal relationship running from energy consumption to economic growth, while for Zambia and Sudan he established a causal relationship running from economic growth to energy consumption. He established a bidirectional causal relationship between economic growth and energy consumption for Cameroon. Kahsai et al. (2012) on a group of 40 sub-Saharan African countries, including Benin established a long-run bidirectional causality between economic growth and energy consumption. In the short run, their finding supports the neutrality hypothesis for the low-income countries of this group, including Benin.

Very few of the studies which have investigated the relationship between energy consumption and economic growth in Benin have focused on electricity consumption (Wolde-Rufael, 2006; Ouedraogo, 2013). Wolde-Rufael (2006) on 17 African countries, including Benin, using the bound testing and Toda Yamamoto approaches to Granger causality in a bivariate framework with electricity consumption per capita as dependent variable, established for four of these countries, including Benin, a long-run relationship between GDP per capita and electricity consumption per capita. However, in the case of Benin and two other African countries the error correction term was neither negative nor significant. In addition, there was a positive unidirectional causality running from electricity consumption per capita to GDP per capita in the case of Benin and the Democratic Republic of Congo, while in Tunisia the same unidirectional causality was established but was negative. In Gabon, there was a positive causal relationship running from GDP per capita to electricity consumption per capita, and a negative unidirectional causality running from electricity consumption per capita to GDP per capita. As mentioned previously, Ouedraogo (2013) established a causal relationship running from electricity consumption to GDP in the long run for ECOWAS countries, including Benin.

While these studies have attempted to analyse the causal relationship between energy and economic growth in different countries, including Benin, it is important to acknowledge that with the differing results provided by these studies, it becomes impossible to conclude the true direction of the causal relationship between energy/electricity consumption and economic growth. These differing results highlight the complexity of the causal relationship between economic growth and energy/electricity consumption, and indicate the necessity to investigate the possibility of a nonlinear or asymmetric relationship between these two variables. Accounting for asymmetry is important as positive shocks or negative shocks on one variable may not necessary have the same impact on another variable. The existence of an asymmetric relationship can be the result of the complexity of the structure of the economy and the various channels through which one variable influences the other. As argued by Chiou-Wei et al. (2008) such complexity appears because of economic shocks, regime change, and change in the economic structure and environment such as modifications in energy prices and policy. In the case of Benin, the country's economic and political regime has encountered several changes. From 1960 to 1971 the country allowed free market and free enterprise, but was shaken by several military coups which have affected its macroeconomic and political stability. From 1972 to 1989, the country was under a socialist and military regime where free market, free enterprise and democracy were restricted. Most major companies and banks were owned by the state, and because of government's political and social agenda, most energy prices were subsidized. Since 1990, when the country returned to democracy, a free market and free enterprise (Schneider, 2000), energy prices (oil and electricity prices) are still subsidized (Hounkpatin, 2013) but to a lower extent than in the previous period. These changes in the economic system (from an economy with a restricted free market and free enterprise to an economy with a totally free market and free enterprise), changes in the political regime (from a socialist and military dictatorship to a democracy) justify the complexity of the economic structure in Benin, as well as the complexity of the various channels through which economic growth and energy consumption influence each other. Therefore, this study uses an asymmetric approach to differentiate between the effect on economic growth of positive and negative shocks on electricity consumption. The aim of the study is to verify if negative shocks on electricity consumption cause a negative shock on real GDP in Benin.

There have been several electricity crises in Benin due to outages of electricity supply to consumers: 1994, 1998, 2006, 2007, 2008, 2012 and 2013 for instance. In the Beninese context electricity supply to consumers is equal to total electricity supply minus electricity losses; in other words it is equal to electricity consumption. These outages of electricity supply to consumers (electricity consumption) or negative shocks on electricity consumption were mainly due to factors such as high dependency on importation of electricity, high rate of electricity losses, a growing domestic demand for electricity, and the inability of the country to invest sufficiently in electricity infrastructure (République du Bénin, 2008). Benin depends on countries such as Ghana, Côte d'Ivoire and Nigeria for the importation of electricity, while these countries are also facing a growing domestic demand for electricity. Whenever electricity outages occur in these countries, there are severe electricity outages in Benin. This has been the case especially with Ghana, which faced droughts in 1983, 1994 and 1998 which reduced the level of water in the Akossombo hydroelectric dam and limited Ghana's capacity for domestic electricity production. In order to fill its domestic electricity supply gap that was caused by these droughts, Ghana reduced its exports of electricity to Benin and Togo. During the drought of 1983, Ghana reduced its exportation of electricity to Benin and Togo by 50%. During the drought of 1994, exportation of electricity toward Benin and Togo was reduced to 40 Mw whereas the initial quantity to be exported was 50 Mw. The drought of 1998 affected both Akossombo and Nangbeto dams. The Nangbeto dam owned by Benin and

Togo contributes to the domestic production of electricity of these two countries. In 1998, Benin and Togo were at the same time facing a reduction in exports of electricity from Ghana, and a reduction of their domestic production of electricity. The initial quantity of electricity that the Beninese Electrical Community (CEB), which ensures the importation of electricity from Ghana, was supposed to supply to Benin and Togo suddenly decreased from 40 Mw to 16 Mw in February 1998, and to 4 Mw in April of the same year (République du Bénin, 2008; Hounkpatin, 2013). These reductions in imports of electricity resulted in severe electricity outages in Benin and affected the sales values of firms in the country as well as the ease of doing business. As reported by World Development Indicators (2016), because of electricity outages, in 2009 and 2016 firms lost 6.2% and 9.4% respectively of their sales value in Benin. Table 1 presents the state of access to electricity by firms in Benin in 2016. It can be seen that 95.6% of firms in Benin experienced electricity outages in that year. The average number of electrical outages per month was 28, while each outage lasted for 3.7 hours on average (Table 1). This situation generated additional costs for firms because they had to acquire electrical generators in order to reduce the impact of electricity outages. Hence, 59.9% of firms in the country own or share a generator, which supplies them with only 37% of their need in terms of electricity (Table 1). This indicates that although many firms use or share a generator, 63% of their electricity consumption is still exposed to outages. With all these significant electricity outages encountered by firms in the country, 60.4% of them have identified electricity as a major constraint for the ease of doing business in Benin (Table 1).

Table 1: State of access to electricity by firms in Benin in 2016

Indicators of ease of doing business as related to access to electricity	All countries average	Sub-Saharan Africa average	Benin average
Percentage of firms experiencing electrical outages	59.1	78.7	95.6
Number of electrical outages in a typical month	6.3	8.5	28.0
If there were outages, average duration of a typical electrical outage (hours)	4.5	5.8	3.7
Percentage of firms owning or sharing a generator	34.4	53.2	59.9
If a generator is used, average proportion of electricity from a generator (%)	20.7	28.2	37.0
Percentage of firms identifying electricity as a major constraint	31.3	39.8	60.4

Source: World Bank (2016) (enterprise survey data)

While electricity outages have negatively affected the ease of doing business and firms' sales values, it is not obvious that they have impeded economic growth. The national policy framework for electricity (République du Bénin, 2008) reported that these electricity outages have impeded economic growth. However, to the best of the writers' knowledge, there is no empirical evidence which has demonstrated that negative shocks on electricity consumption have caused negative shocks on economic growth in Benin. In addition, according to the World Development Indicators

(2017), over 44 years (1971-2014) (the period for which data was available at the time of analysis), the share of electricity consumption in total primary energy consumption in the country has been very low: it has never exceeded 2.07%. This indicates that it is possible that negative shocks on electricity consumption have not caused negative shocks on economic growth, because the proportion of electricity consumption in total primary energy consumption is very low. It therefore becomes necessary to verify empirically if negative shocks on electricity consumption have caused negative shocks on economic growth. The current study conducts such verification. As said previously, it uses an asymmetric approach to separate the effect on economic growth of negative shocks on electricity consumption from that of positive shocks on electricity consumption. Using a symmetric approach will not allow such separation, which is essential as the study focuses specifically on the effect of negative shocks. The study will verify if negative shocks on electricity consumption have caused negative shocks on real GDP. Knowing if negative shocks on electricity consumption have or have not caused negative shocks on economic growth will add value to the policy dialogue on electricity security in Benin, and will contribute to the formulation of the national policy framework on electricity security in the country. It will also add value to the existing literature on asymmetric causality between energy and economic growth, as there is no study (to the best of the writers' knowledge) that has specifically investigated the causal effect on economic growth of negative shocks on energy/electricity consumption in the Beninese context.

This paper starts by reviewing the theoretical foundation of the relationship between economic growth and energy consumption, as well as previous studies on the asymmetric relationship between electricity consumption and economic growth.

2 LITERATURE REVIEW

2.1 Theoretical foundation on the relationship between energy and economic growth

For several decades, energy was not considered as a factor of production as are capital and labour. Growth models of Solow (1956) which consider technological change as exogenous, and endogenous growth models such as the Schumpeterian model, the "learning by doing" model developed by Arrow (1962), and the "induced innovation" model of Hicks (1932), do not account for energy among factors of production.

Differing from theorists of these growth models, ecological economists (Ayres and Warr, 2005, 2009; Costanza, 1980; Georgescu-Roegen, 1971; Murphy and Hall, 2010; Cleveland et al., 1984; Hall et al., 1986, 2001, 2003) argued that energy is fundamental for economic growth. In alignment with them, some scholars in economic history (Allen, 2009; Wrigley, 1988) and geography (Smil, 1994) argued that energy is an important factor of economic growth and was also one of the main factors which determined the industrial revolution. Wrigley (1988) argued that the use of a new type of energy such as fossil fuel has leveraged existing constraints on the supply of energy, the production process, and economic growth. He compared British and Dutch economies: in the Dutch economy, capital accumulation was constrained by the lack of a continuous availability of energy, while that constraint was lifted in the British economy because of the availability of coal mines. Hence, the industrial revolution occurred in the British economy while it could have occurred in both economies. In alignment with Wrigley (1988), Allen (2009) and Stern and Kander (2010) point out the importance of energy in the industrial revolution in the British economy. Ecological economists such as Hall et al. (1986, 2003) and Cleveland et al. (1984) argued that an increase in productivity is mainly the result of an increase in the use of energy, and economic growth occurs only as a result of increases in the use of energy.

In contrast to Solow (1956) and theorists of the endogenous growth model, Stern and Kander (2010) argued that energy is fundamental for economic growth and should be considered as a factor of production, as are capital and labour. His view differs from the ecological economists' views as he posits that energy is not the only factor of production. According to Stern (1997), there is a limit to the substitution of capital and labour for energy, hence energy remains an important factor of production. Stern and Kander (2010) posit that energy is fundamental for economic growth, and the production process requires energy, labour and capital. He proposed a modified version of Solow's (1956) model of economic growth by including energy as a factor of production. Based on these theories on the relationship between energy and economic growth, a positive correlation between economic growth and energy can be expected. In other words, positive shocks on energy consumption are associated with positive shocks on economic growth, while negative shocks on energy consumption are associated with negative shocks on economic growth.

2.2 Empirical literature on the asymmetric relationship between energy/electricity consumption and economic growth

There have been very few studies which have used an asymmetric approach to differentiate between the effect of positive and negative shocks when investigating the relationship between energy/electricity consumption and economic growth. The main reason is that the ability to make such differentiation was only possible recently with Granger and Yoon's (2002) asymmetric cointegration (denoted "hidden cointegration") and Hatemi-J's (2012) asymmetric causality test. Because the aim of this study is to investigate the causal effect on economic growth of negative shocks on electricity consumption, the focus is mostly on studies that have investigated the asymmetric causal relationship between economic growth and energy/electricity consumption, and differentiated between the causal effect of positive and negative shocks. Among the few studies which have done such investigation, some have focused on total renewable energy, others on total energy, but very few have focused on disaggregated energy. Shahbaz et al. (2017) investigated the asymmetric causal relationship between growth and energy consumption in India, and established an asymmetric causality running from negative shocks on energy consumption to economic growth. Ranjbar et al. (2017) investigated the growth-energy nexus in South Africa using the asymmetric frequency domain methodology, and established that negative shocks on energy consumption cause negative shocks on economic growth. One of their main conclusions was that when energy consumption decreases, economic growth also decreases, however an increase in energy consumption will not necessarily lead to an increase in economic growth. Destek (2016) established that negative shocks on renewable energy consumption in newly industrialized countries lead to positive shocks in real GDP for Mexico and South Africa, while negative shocks in renewable energy consumption lead to negative shocks in real GDP for India. There was no causal relationship between renewable energy consumption and real GDP for Malaysia and Brazil. Bayramoglu and Yildirim (2017) established an asymmetric relationship between energy consumption and economic growth in the long run in the USA, while there was no asymmetric relationship between these two variables in the short run. Ocal et al. (2013) found no asymmetric causality between coal consumption and economic growth in Turkey. Alper and Oguz (2016), in a study of new members of the European Union, found mixed results on the relationship between renewable energy and economic growth from a group of countries to another: the growth hypothesis was supported for some countries while the neutrality hypothesis was supported for others, the conservative hypothesis was supported for the Czech Republic. Bayat et al. (2017) established that positive shocks on electricity consumption in Turkey do not induce an increase in economic growth, while negative shocks on electricity consumption induce a reduction in economic growth. They also established that both positive and negative shocks on economic growth have a causal effect on electricity consumption. Chen et al. (2017) established the existence of an asymmetric causal relationship between energy consumption (coal and oil) and economic growth in China. Gupta et al. (2017) established that there is not enough evidence in South Africa to ascertain that total, non-residential and residential electricity demand have an asymmetric behaviour (in other words, evidence of an asymmetric behaviour of total, non-residential and residential electricity demand in South Africa is weak). Tugcu and Topcu (2018) established an asymmetric relationship between total energy consumption and economic growth in G7 countries. Hatemi-J and Uddin (2012) established that negative shocks on energy consumption per capita cause negative shocks on GDP per capita in the USA, while no evidence of causality was found between positive shocks on energy consumption per capita and positive shocks on GDP per capita. Tiwari (2014) established an asymmetric causality between economic growth and growths of coal consumption, natural gas consumption, total primary energy consumption, total renewable energy consumption, and electricity consumption in the US economy. Particularly, he established that positive shocks on economic growth caused positive shocks on coal consumption, while positive shocks on electricity consumption caused positive shocks on economic growth. In addition, he established a bidirectional causal relationship between economic growth and growth of natural gas consumption, growth of total primary energy consumption and economic growth, and growth of total renewable energy and economic growth. Moreover, he ascertained that negative shocks on growth of coal consumption caused negative shocks on economic growth, and negative shocks on growth of total renewable energy caused negative shocks on economic growth.

One of the limitations of these studies is that many of them are cross-country analyses, hence are very limited in terms of country-specific policy recommendations. Some, even though they have focused on a specific country, have investigated the link between total energy (aggregate energy) and growth; therefore, they are very limited in terms of policy recommendations for disaggregated energy. Only few have focused on specific types of energy such as coal, oil, and electricity (Tiwari, 2014; Bayat et al., 2017; Gupta et al., 2017; Chen et al., 2017; Ocal et al., 2013). As mentioned previously, not all types of energy have the same weight in an economy: some countries are oil dependent, others rely heavily on imports of electricity, and yet others rely heavily on natural gas revenues. Hence, studies on disaggregate energy-growth nexus are very important for policy recommendations on specific types of energy. Olayeni (2012) used the hidden cointegration approach to analyse the growth-energy nexus of 12 sub-Saharan African countries, including Benin. He did not extend the analysis to the asymmetric causal relationship between energy and growth, and his study focused on total energy. To the best of the writers' knowledge, no study has investigated the causal effect on economic growth of negative shocks on electricity consumption in the context of Benin in a country-specific analysis. As said before, investigating such causal effect involves a separation of the effect on economic growth of negative shocks on electricity consumption from that of positive shocks on electricity consumption. As mentioned previously, using a symmetric approach will not allow such differentiation, but an asymmetric approach will allow such differentiation. As the relationship between electricity consumption and economic growth can be asymmetric because of the complexity of the channels and mechanisms through which these two variables influence each other, an asymmetric approach will be used when investigating the effect on economic growth of negative shocks on electricity consumption. The current study therefore investigates the causal effect on economic growth (real GDP) of negative shocks on electricity consumption using an asymmetric approach.

2.3 Contribution of the study

The current study contributes to the dialogue on the economic burden of disruption risks to the electricity supply in Benin. It also contributes to the formulation of policies for electricity security in that country. As said previously, although the national policy framework for electricity has stipulated that electricity shortages caused a reduction in economic growth in Benin, there is no empirical evidence (to the best of the writers' knowledge) which has demonstrated that negative shocks on electricity consumption have caused negative shocks on economic growth. The current study will ascertain for the national policy framework for electricity the existence or not of a causal effect of electricity shortages on economic growth. In addition to its contribution to electricity supply policy in

Benin, the current study will also add value to the literature on electricity security and economic growth.

3 METHODOLOGY

3.1 Empirical model

Unlike neoclassic economists who consider labour, capital and technology as factors of production, Alam (2006) indicated the necessity of including energy among factors of production: energy is used for production, and is a driver of economic growth, therefore it should be considered as a factor of production like capital and labour. Following the work of Odularu and Okonkwo (2009), Ghali and El Sakka (2004), Shabaz (2015) and Oh and Lee (2004a, 2004b), the writer developed a growth model to describe the relationship between electricity consumption and economic growth, as:

$$Y_t = f(A, EC_t, K_t, L_t) \qquad 1$$

where*, A, EC, L* and *K* are technology, electricity consumption, labour and capital respectively, and *Y* represents real GDP.

However, the focus of this study is not to model the relationship between electricity consumption and economic growth and estimate the coefficients on the different explanatory variables (electricity consumption, labour and capital). Rather, the focus is to verify if negative shocks on electricity consumption have caused negative shocks on economic growth. As discussed previously, such verification will be done using an asymmetric approach described in the analytical framework section.

3.2 Analytical framework

First, in order to avoid spurious regression, it is important to check the stationarity of the series. A variety of unit root procedures tests the null hypothesis of the existence of a unit root against the alternative hypothesis of the absence of unit root. Significant among them are the Elliott, Rothenberg and Stock (1996) (DF-GLS), Augmented Dickey Fuller (ADF), and Phillips–Perron (PP) tests. Other tests such as Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test the null hypothesis of the absence of unit root (evidence of stationarity) against the alternative hypothesis of the presence of unit root. However, the PP and ADF tests have a lower power in testing unit roots than DF-GLS, because they fail to detect I(0) series with patterns which resemble I(1) series. Hence, the unit root tests used in this study were the ADF, PP, KPSS and DF-GLS tests.

Perron (1989) argued that the results of the ADF test are biased when there is evidence of structural breaks among data. The Beninese economy encountered several different shocks over the last few years: the devaluation of the CFA currency by 50% in 1994, the electricity crises of 1984, 1994, 1998, 2006, 2007, 2008, 2012 and 2013, and the shift from a socialist regime to free market, private ownership and democracy in 1990 (Hounkpatin, 2013; Schneider, 2000; Constant, 2012). Hence it was important to also apply to our series, in addition to the above tests, a unit root test which accounts for structural breaks. Such a unit root test with structural break is the Zivot Andrews (ZA) unit root test, which allows a single breakpoint. A unit root with single breakpoint was applied because of the small size of the series (44 observations).

Second, the asymmetric causality test proposed by Hatemi-J (2012) was used to investigate the causal relationship between the variables. It follows the procedure of Toda and Yamamoto (1995) and separates the effect of positive shocks from that of negative shocks. The idea of separating the effect of positive shocks from that of negative shocks was initially developed by Granger and Yoon (2002). Their work was limited to cointegration analysis where they differentiated between the effect of positive and negative shocks. As said before, their asymmetric cointegration was denoted the "hidden cointegration". Hatemi-J (2012) extended their work to asymmetric causality. He defines integrated variables Z_1 and Z_2 as a random walk in the following general expressions:

$$Z_{1t} = Z_{1t-1} + e_{1t} = Z_{10} + \sum_{i=1}^{t} e_{1i}, \qquad t \in \mathbb{N}^* \qquad 2$$

$$Z_{2t} = Z_{2t-1} + e_{2t} = Z_{20} + \sum_{i=1}^{t} e_{2i}, \qquad t \in \mathbb{N}^* \qquad 3$$

where Z_{10} and Z_{20} represent the initial values of Z_{1t} and Z_{2t}, respectively, and e_i represents the error terms (white noise). Hatemi-J (2012) argued that the error terms can be decomposed into positive and negative shocks in the following equations:

$$e_{1i} = e_{1i}^{+} + e_{1i}^{-} \qquad i \in \mathbb{N}^* \qquad 4$$

$$e_{2i} = e_{2i}^{+} + e_{2i}^{-} \qquad i \in \mathbb{N}^* \qquad 5$$

where e_{1i}^{+} and e_{1i}^{-} represent respectively positive and negative shocks on the variable Z_1, and e_{2i}^{+} and e_{2i}^{-} represent respectively positive and negative shocks on the variable Z_2. These positive and negative shocks can also be expressed as follows:

$$e_{1i}^{+} = (\max e_{1i}, 0) \text{ and } e_{1i}^{-} = (\min e_{1i}, 0), \qquad i \in \mathbb{N}^* \qquad 6$$

$$e_{2i}^{+} = (\max e_{2i}, 0) \text{ and } e_{2i}^{-} = (\min e_{2i}, 0), \qquad i \in \mathbb{N}^* \qquad 7$$

where the expression *(max e_i, 0)* indicates that the values of e_i (whether e_{1i} or e_{2i}) are superior to 0, while the expression (*min e_i, 0*) indicates that values of e_i (whether e_{1i} or e_{2i}) are inferior to 0.

Hence Equations 2 and 3 can be respectively re-expressed in an asymmetric framework as:

$$Z_{1t} = Z_{1t-1} + e_{1t} = Z_{10} + \sum_{i=1}^{t} e_{1i}^{\ +} + \sum_{i=1}^{t} e_{1i}^{\ -}, \qquad t \in \mathbb{N}^* \tag{8}$$

$$Z_{2t} = Z_{2t-1} + e_{2t} = Z_{20} + \sum_{i=1}^{t} e_{2i}^{\ +} + \sum_{i=1}^{t} e_{2i}^{\ -}, \qquad t \in \mathbb{N}^* \tag{9}$$

where Z_{1t} is a function of its initial value Z_{10} and the partial sum of its positive and negative variations (shocks) ($\sum e_{1i}^{+}$ and $\sum e_{1i}^{-}$), and Z_{2t} is a function of its initial value Z_{20} and the partial sum of its positive and negative variations (shocks) ($\sum e_{2i}^{+}$ and $\sum e_{2i}^{-}$). The graphs of electricity consumption and real GDP, as well as the unit root tests results, showed that these two variables followed a random walk process (see empirical results section). Following the asymmetric framework of Hatemi-J (2012) which separates negative shocks from positive shocks in Equations 8 and 9, real GDP (*RGDP*) and electricity consumption (*EC*) (both variables are random walk; see Section 3.3 for further explanation) have been expressed as a function of their initial value and the partial sum of their positive and negative shocks as:

$$RGDP_t = RGDP_0 + \sum_{i=1}^{t} \Delta RGDP_i^{+} + \sum_{i=1}^{t} \Delta RGDP^{-} \tag{10}$$

$$EC_t = EC_0 + \sum_{i=1}^{t} \Delta EC_i^{+} + \sum_{i=1}^{t} \Delta EC^{-} \tag{11}$$

where RGDP0 and EC0 represent the initial value of real GDP and total electricity consumption in their respective series, ∆RGDP+ and ∆EC+ represent the positive variations of real GDP and electricity consumption respectively, and ∆RGDP- and ∆EC- represent the negative variations of real GDP and electricity consumption respectively. For simplicity, the partial sum of positive variations of any variables will be denoted by the name of the variable and the suffix Pos and the partial sum of negative variations of any variables will be denoted by the name of the variable and the suffix Neg. In other words we will have the following:

For real GDP:

$$\sum_{i=1}^{t} \Delta RGDP_i^{+} = \sum_{i=1}^{t} \max(\Delta RGDP_i, 0) = RGDPPos_t, \quad t \in \mathbb{N}^* \tag{12}$$

$$\sum_{i=1}^{t} \Delta RGDP_i^{-} = \sum_{i=1}^{t} \min(\Delta RGDP_i, 0) = RGDPNeg_t, \quad t \in \mathbb{N}^* \tag{13}$$

For electricity consumption:

$$\sum_{i=1}^{t} \Delta EC^{+} = \sum_{i=1}^{t} \max(\Delta EC, 0) = ECPos_t, \quad t \in \mathbb{N}^* \qquad 14$$

$$\sum_{i=1}^{t} \Delta EC_i^{-} = \sum_{i=1}^{t} \min(\Delta EC_i, 0) = ECNeg_t, \quad t \in \mathbb{N}^* \qquad 15$$

where *RGDPPos* and *ECPos* represent the partial sums of positive variation of real GDP and electricity consumption respectively; and *RGDPNeg* and *ECNeg* represent the partial sums of negative variation of real GDP and electricity consumption respectively. As said previously, max (variable, 0) indicates that the values of such variable (either Δ*RGDP* or Δ*EC*) are positive, while min (variable, 0) indicates that the values of such variable (either Δ*RGDP* or Δ*EC*) are negative. Positive shocks on real GDP and electricity consumption are represented respectively by *RGDPPos* and *ECPos*, while *RGDPNeg* and *ECNeg* represent negative shocks on real GDP and electricity consumption respectively. The aim of the study is to verify if negative shocks on electricity consumption have caused negative shocks on economic growth (proxied here by real GDP). In other words, it is to verify, first, if *ECNeg* has caused *RGDPNeg*. To make such verification we use the asymmetric causality test of Hatemi-J (2012), which separates the effect of negative shocks from that of positive shocks.

Hatemi-J (2012) used the following VAR framework to run the asymmetric causality test:

In the case of causality between positive shocks:

$$Z_t^{+} = w + B_1 Z_{t-1}^{+} + ... + B_p Z_{t-p}^{+} + \varepsilon_t^{+} \qquad 16$$

In the case of causality between negative shocks:

$$Z_t^{-} = w + B_1 Z_{t-1}^{-} + ... + B_p Z_{t-p}^{-} + \varepsilon_t^{-} \qquad 17$$

where w represents a 2x1 intercepts' vector, Z_t^{+} represents a 2x1 variables' vector (Z_{1t}^{+}, Z_{2t}^{+}), Z_t^{-} represents a 2x1 variables' vector (Z_{1t}^{-}, Z_{2t}^{-}), B_k represents a 2x2 matrix parameters with lag order k ($k = 1,....p$), ε_t^{+} and ε_t^{-} represents a 2x1 error terms' vector. Prior to running a causality test using a VAR framework, it is necessary to identify the optimal lag length of such VAR framework. Hatemi-J (2012) developed a new lag selection criterion as:

$$HJC = \ln(\left|\widehat{\theta}_k\right|) + k[\left(n^2 \ln T + 2n^2 \ln(\ln T)\right) / 2\mathrm{T}], \quad k = 0, ..., p \qquad 18$$

where $|\theta_k|$ represents the determinant of the computed variance-covariance matrix of the VAR model's residuals, k represents the lag order in the VAR model, and T and n represent respectively the number of observations and the number of equations in the VAR model with lag order k. The lag order that minimizes Hatemi-J's (2012) new criteria is the optimal. Hatemi-J (2012) also argued that a Wald test can be used to investigate asymmetric causality between variables. This is possible as long the asymptotic properties of the Wald test are not violated. Once the selection of the optimal lag is completed, the next step is to test the validity of the null hypothesis stated as:

i) in the case of the causal effects of positive shocks:

the kth element of Z_{1t}^{+} does not impact the wth element of Z_{2t}^{+}

ii) in the case of causal effect of negative shocks:

the kth element of Z_{1t}^{-} does not impact the wth element of Z_{2t}^{-}.

In other words, and according to Hatemi-J (2012), the null hypothesis (H0) in both cases is:

H0: the row *w*, column *k* element in B_r equals zero for $r = 1,\ldots p$.

In general, causality tests designed on the basis of bootstrapping distribution have superior power and size properties compared to causality tests designed on the basis of asymptotic distribution, especially in cases where the asymptotic properties of the latter are violated (Hatemi-J, 2012). One of the advantages of using the asymmetric causality test of Hatemi-J (2012) is that it overcomes the limitation of the Wald test in terms of normality and ARCH effect. When there is presence of ARCH effect and when the data does not have a normal distribution, then the asymptotic properties of the Wald test are violated. To solve these issues, Hatemi-J (2012) proposed the use of bootstrapping simulations. These simulations are done repeatedly ten thousand times and during each simulation the Wald test statistic is calculated. This approach helps to generate the distribution of the Wald test. After generating the distribution of the bootstrapped Wald test, the next step is to calculate the bootstrapped critical values. For any β-level of significance, the bootstrapped critical values (CV_β) are estimated by identifying the β^{th} upper quantile of the bootstrapped Wald test's distribution. Lastly, the Wald test statistic is estimated based on the original data, and its value is compared to the bootstrapped critical values (CV_β). If the value of the Wald test statistic estimated last is greater than the bootstrapped critical values (CV_β), then the null hypothesis stating that there is no causality is rejected. In other words, there is evidence of an asymmetric causality between the variables (either between the positive shocks Z_{1t}^{+} and Z_{2t}^{+}, or between the negative shocks Z_{1t}^{-} and Z_{2t}^{-}).

Apart from the statistical development of his asymmetric causality test, Hatemi-J (2012) also developed some written codes in GAUSS which are used to run the test. This study makes use of such GAUSS codes to run the asymmetric causality test between the variables.

3.3 Data

Following Shabaz et al. (2017) and Hoang et al. (2016), initially all variables were converted into their logarithmic form, in order for them to have proper distribution properties. Annual series of real

GDP (RGDP) and electricity consumption (EC) were collected over the period 1971-2014. Series of RGDP are expressed in constant 2010 US$, while series of EC are expressed in kilowatt-hours (kWh). All series (RGDP and total EC) have been collected from the World Development Indicators (2018) website. The series for total EC was obtained by multiplying total EC per capita by total population (also collected from the World Development Indicators (2018) website). Graphs of all variables (EC, RGDP, logEC, logRGDP) show that they all have an intercept and a trend (Figures 1, 2, 3 and 4).

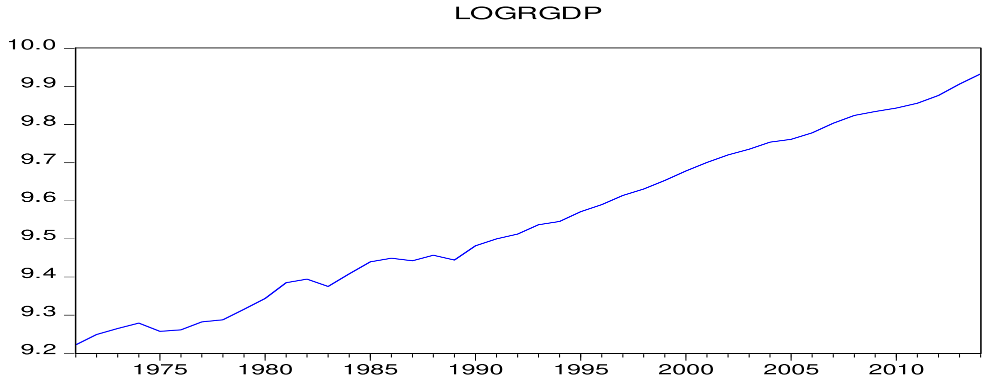

Figure 1: History of the logarithm of real GDP in Benin (1971-2014)

Source: World Development Indicators (2018)

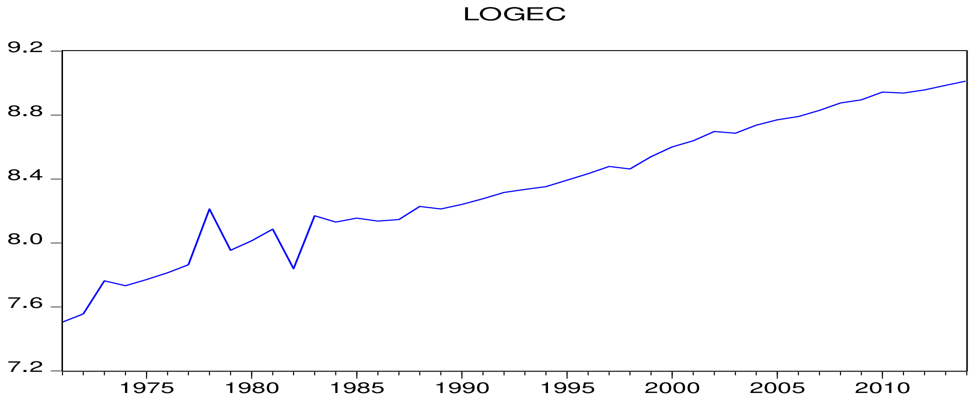

Figure 2: History of the logarithm of electricity consumption in Benin (1971-2014)

Source: World Development Indicators (2018)

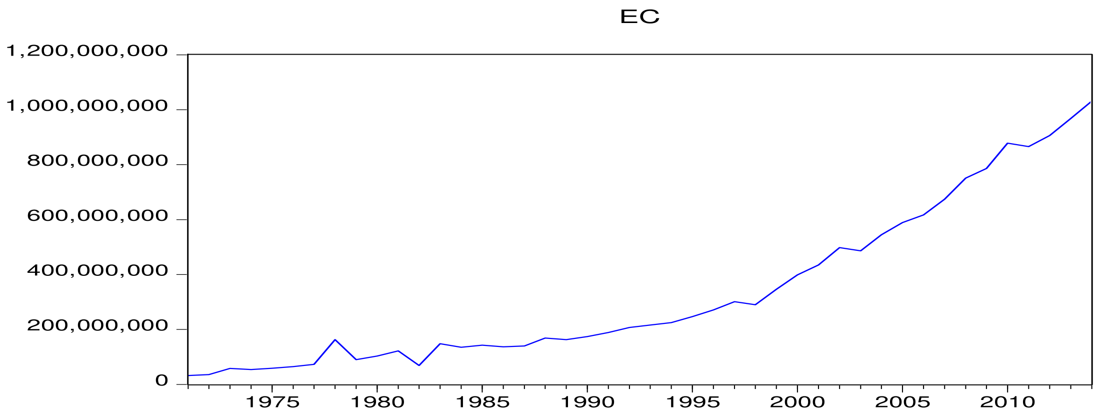

Figure 3: History of electricity consumption (in kWh) in Benin (1971-2014)

Source: World Development Indicators (2018)

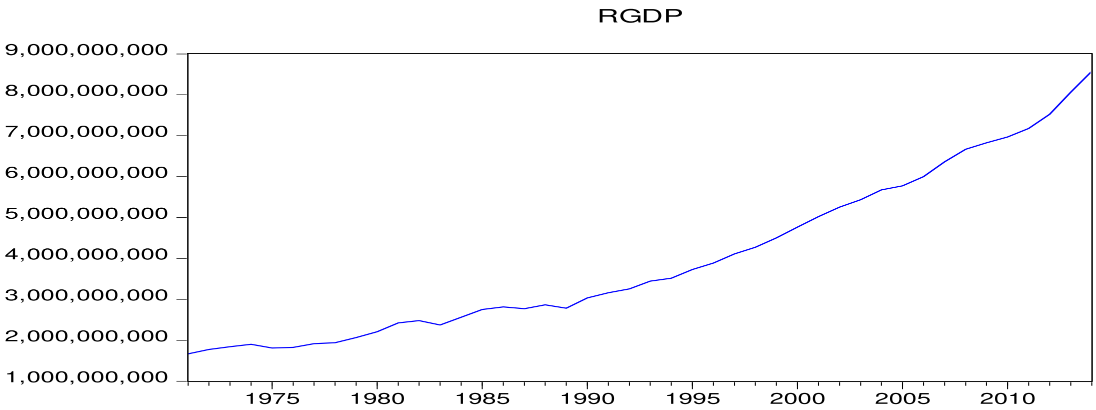

Figure 4: History of real GDP constant 2010 US$ (1971-2014)

Source: World Development Indicators (2018)

Hatemi-J et al. (2015) argued that it is important to ensure that variables are random walk before using an asymmetric approach to decompose them into the cumulative sum of their positive and negative variations. On one hand the different unit root tests (ADF test, PP and KPSS tests, and ZA test with structural break) revealed that the logarithm of electricity consumption (logEC) is stationary at level with intercept and trend (see empirical results on unit root tests in Section 4 for further details). Hence, logEC does not follow the pattern of a random walk, and therefore, in alignment with Hatemi-J et al. (2015), we cannot decompose logEC in the partial cumulative sum of its positive and negative variation. On the other hand, the different unit root tests applied at both level and first difference with intercept and trend revealed that both EC and RGDP (in their natural form) are I(1) (stationary at first difference). Hence, they follow the patterns of a random walk, and in alignment with Hatemi-J et al. (2015) can be decomposed in the partial cumulative sum of their positive and negative variation. Consequently, this study did not use the variables (EC and RGDP) in their logarithmic form; rather these variables were used in their natural form without any transformation. In other words, the variables used in this study were EC and RGDP rather than logEC and logRGDP.

4 EMPIRICAL RESULTS

4.1 Results of lag selection procedure and unit root tests

Before running unit root tests for each of these variables, it is important to identify the optimal lag. Enders (2004) stipulates that the selection of lags for annual data should be in the range 1 to 3. Hence, we have chosen first 1, then 2, and finally 3 as the maximum lag when proceeding for lag specification in the optimum lag selection procedure. The results of the lag selection criteria are described below in Table 2, which shows that three criteria (the sequential modified LR statistic, Schwarz information criterion, and Hannan-Quinn information criterion) out of five (sequential modified LR statistic, Akaike information criterion, Final prediction error, Schwarz information criterion, Hannan-Quinn information criterion) selected one (01) as the optimal lag when the maximum lag chosen is two (02) or three (03). When the maximum lag chosen is one (01), all five criteria choose one (01) as optimal lag. Hence, one (01) was chosen as the maximum lag when running unit root tests. However, two (02) was chosen as the maximum lag when running the Zivot Andrews (ZA) unit root test on electricity consumption (EC) at first difference with intercept and trend: the ZA test cannot be run with one (01) as the maximum lag in that specific case (Eviews 10 cannot run the ZA test with one (01) as the maximum lag in that specific case).

Table 2: Result of the optimal lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
Choice of 1 as maximum lag						
0	-1800.284	NA	8.72e+33	83.82717	83.90909	83.85738
1	-1648.780	281.8681*	9.15e+30*	76.96652*	77.21226*	77.05714*
Choice of 2 as maximum lag						
0	-1758.565	NA	8.81e+33	83.83642	83.91917	83.86675
1	-1611.205	273.6689*	9.55e+30	77.00975	77.25798*	77.10073*
2	-1606.239	8.748740	9.14e+30*	76.96377*	77.37750	77.11542
Choice of 3 as maximum lag						
0	-1716.631	NA	8.80e+33	83.83567	83.91926	83.86611
1	-1573.453	265.4032*	9.91e+30	77.04650	77.29726*	77.13781*
2	-1568.563	8.586780	9.51e+30*	77.00310*	77.42104	77.15529
3	-1566.278	3.789997	1.04e+31	77.08675	77.67187	77.29982

Notes: (*) indicates the optimal length selected by the criterion
LR: sequential modified LR statistic
FPE: Final prediction error;
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Authors’ estimation

As noted previously (in Section 3.3), graphs of both electricity consumption and real GDP show that both variables (EC and RGDP) have an intercept and a trend. Hence, different unit root tests have been applied at level with intercept and trend and at first difference with intercept and trend. Table 3 presents the results of the different unit root tests (DF-GLS, ADF, PP, KPSS and ZA tests). All tests revealed that EC and RGDP are I(1) (non-stationary at level, but stationary at first difference). Hence, as said before, they have the pattern of a random walk, and in alignment with

Hatemi-J et al. (2015), they can be split into the partial cumulative sum of their positive and negative variations. As mentioned previously, the logarithm of EC (logEC) is stationary at level according to the result of ADF, PP, KPSS and ZA tests. Hence, it does not follow strictly the patterns of a random walk, and in alignment with Hatemi-J et al. (2015), we cannot spilt log(EC) into the partial cumulative sum of its positive and negative variations. As explained previously, because the logarithm of EC (logEC) is not a random walk, we did not use logEC and the logarithm of real GDP (logRGDP) in this study: instead, we used EC and RGDP which are random walks. Both RGDP and EC have been split into the partial cumulative sum of their positive and negative variations in order to run an asymmetric causality test.

Table 3: Unit root test results

Unit root tests			**Variables**			
			RGDP	**EC**	**logRGDP**	**logEC**
ADF	Level	Intercept and trend	1.372837 (1)	0.798372 (1)	-2.285061 (1)	-6.173720 (1)***
	1st difference	Intercept and trend	-4.883822 (1)***	-10.19749 (1)***	-6.270955 (1)***	---
DF-GLS	Level	Intercept and trend	-0.201127 (1)	-0.227188 (1)	-2.115119 (1)	-3.155564 (1)
	1st difference	Intercept and trend	-4.793749 (1)***	-10.39263 (1)***	-6.068452 (1)***	-8.448562 (1)***
PP	Level	Intercept and trend	2.650053	0.765350	-1.979705	-6.173717***
	1st difference	Intercept and trend	-4.603013***	-10.19749***	-6.875425***	.
KPSS	Level	Intercept and trend	0.226184***	0.216648***	0.186708**	0.079509
	1st difference	Intercept and trend	0.119100	0.118253	0.146000**	---
ZA	Level	Intercept and trend	-0.942944 (1) [1987]	-3.595469 (1) [1997]	-3.696128 (1) [1987]	-8.065377 (1)*** [1982]
	1st difference	Intercept and trend	-5.470700 (1)** [2005]	-11.67329 (2)*** [1979]	-6.753444 (1)*** [1982]	---

Notes: (***) and (**) indicate 1% and 5% significance levels respectively

The numbers in round brackets represent the maximum lag selected to run the unit root test.

The numbers in square brackets represent the break dates.

Source: Authors' estimation

4.2 Causality test results

4.2.1 History of partial sum of positive and negative variations of electricity consumption and real GDP

Figure 5 represents the history of partial cumulative sum of positive variations (ECPos) and negative variations (ECNeg) of EC, while Figure 6 represents history of the partial cumulative sum of positive and negative variations of RGDP in Benin. It can be seen in both figures that the partial cumulative sum of positive variations tend to grow faster than the partial cumulative sum of negative variations. However, this does not indicate that the partial cumulative sum of positive variation of one variable may cause the partial cumulative sum of positive variations of the other variable.

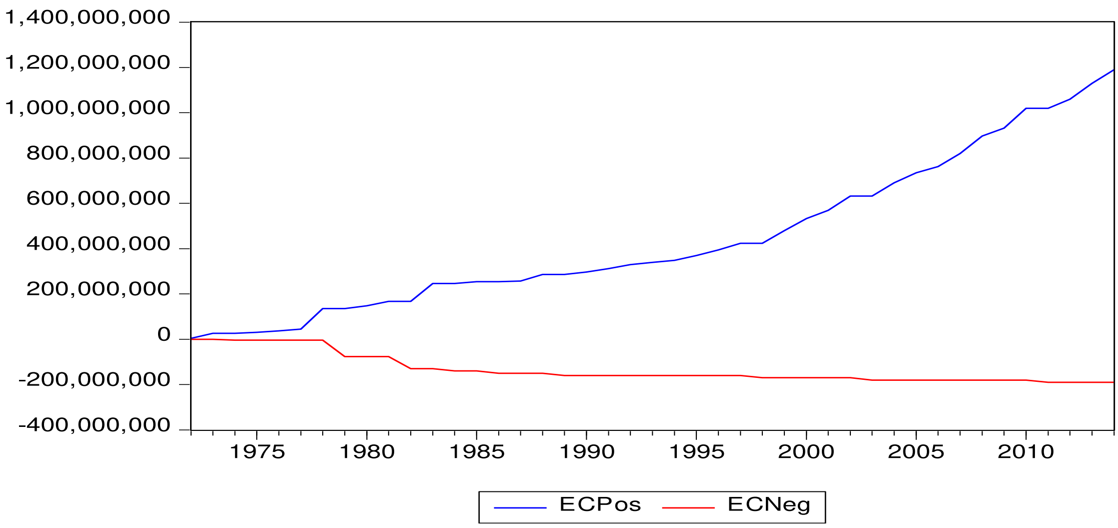

Figure 5: History of the partial cumulative sum of positive and negative variations of electricity consumption (1972-2014)

Source: Authors' estimation based on data from the World Development Indicators (2018)

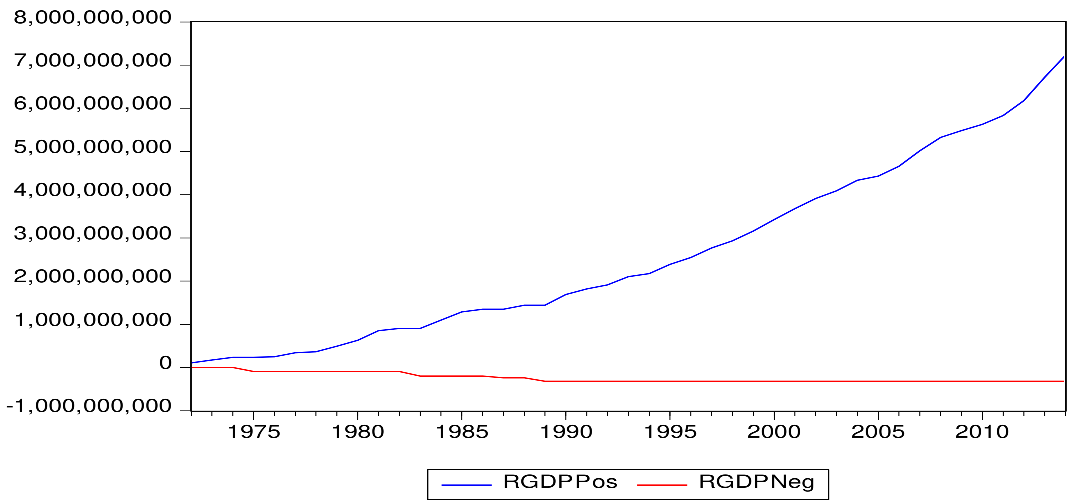

Figure 6: History of the partial cumulative sum of positive and negative variations of real GDP (1972-2014)

Source: Authors' estimation based on data from the World Development Indicators (2018)

4.2.2 Results of Doornik-Hansen (2008) multivariate normality test and the multivariate ARCH test of Hacker and Hatemi-J (2005)

Before using Hatemi-J's (2012) asymmetric causality test, we first checked if it was possible to use a Wald test that has an asymptotic distribution to investigate the asymmetric causality between ECNeg and RGDPNeg, and between ECPos and RGDPPos. To do this, we verified if there was ARCH effect among the data, and if the data had a normal distribution property. Therefore, the Doornik-Hansen (2008) multivariate normality test and the multivariate ARCH test of Hacker and Hatemi-J (2005) were applied to the partial cumulative sum of negative variations of both variables (ECNeg, RGDPNeg) and to the partial cumulative sum of positive variations of both variables (ECPos, RGDPPos). Table 4 presents the results of the multivariate ARCH test of Hacker and Hatemi-J (2005) applied to the model (ECNeg, RGDPNeg) and the model (ECPos, RGDPPos). Both p-values based on asymptotic and p-value based on bootstrapping are more than 5% (and even more than 10%). This indicates that there is no ARCH effect among the data in the models ECNeg, RGDPNeg and ECPos, RGDPPos. However, we also need to ensure the normality property of the data before running an asymmetric causality test using the Wald test.

Table 4: Result of the multivariate ARCH test of Hacker and Hatemi-J (2005) for the models ((ECNeg, RGDPNeg) and (ECPos, RGDPPos)

Model (ECNeg, RGDPNeg)	
p-values based on asymptotics, for ARCH orders of 1, 2, 3 respectively.	0.595280
p-values based on bootstrapping, for ARCH orders of 1, 2, 3 respectively.	0.272000
Model (ECPos, RGDPPos)	
p-values based on asymptotics, for ARCH orders of 1, 2, 3 respectively.	0.668370
p-values based on bootstrapping, for ARCH orders of 1, 2, 3 respectively.	0.602000

Source: Authors' estimation in using the GAUSS codes provided by Hacker and Hatemi-J (2005) and based on data from the World Development Indicators (2018)

Before running Doornik-Hansen's (2008) multivariate normality test, we first perform a lag selection. Tables 5 and 6 present the results of the lag selection procedure for both VAR models (ECNeg, RGDPNeg and ECPos, RGDPPos). It can be seen that all five criteria (sequential modified LR statistic, Akaike information criterion (AIC), Final prediction error (FPE), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ)) suggested one (01) as the optimal lag in both VAR models.

Table 5: Result of the optimal lag selection for the VAR model (ECNeg, RGDPNeg)

Lag	LogL	LR	FPE	AIC	SC	HQ
Choice of 1 as maximum lag						
0	-1608.974	NA	7.10e+30	76.71306	76.79581	76.74339
1	-1514.309	175.8067*	9.47e+28*	72.39567*	72.64391*	72.48666*
Choice of 2 as maximum lag						
0	-1568.645	NA	6.45e+30	76.61681	76.70040	76.64725
1	-1477.716	168.5498*	9.29e+28*	72.37641*	72.62718*	72.46773*
2	-1476.533	2.077772	1.07e+29	72.51382	72.93176	72.66601
Choice of 3 as maximum lag						
0	-1527.777	NA	5.67e+30	76.48886	76.57331	76.51939
1	-1440.899	160.7256*	9.00e+28*	72.34493*	72.59826*	72.43653*
2	-1439.146	3.066548	1.01e+29	72.45731	72.87953	72.60997
3	-1433.778	8.857151	9.47e+28	72.38891	72.98002	72.60264

Notes: (*) indicates the optimal length selected by the criterion
LR: sequential modified LR statistic
FPE: Final prediction error;
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Authors' estimation

Table 6: Result of the optimal lag selection for the VAR model (ECPos, RGDPPos)

Lag	LogL	LR	FPE	AIC	SC	HQ
Choice of 1 as maximum lag						
0	-1750.432	NA	5.98e+33	83.44916	83.53190	83.47949
1	-1595.021	288.6201*	4.42e+30*	76.23912*	76.48736*	76.33011*
Choice of 2 as maximum lag						
0	-1708.804	NA	6.01e+33	83.45385	83.53744	83.48428
1	-1557.995	279.5477*	4.66e+30*	76.29245*	76.54322*	76.38376*
2	-1555.442	4.482903	5.01e+30	76.36305	76.78099	76.51524
.Choice of 3 as maximum lag						
0	-1666.944	NA	5.97e+33	83.44721	83.53165	83.47774
1	-1520.730	270.4958*	4.87e+30*	76.33651*	76.58984*	76.42811*
2	-1518.305	4.243825	5.28e+30	76.41526	76.83748	76.56792
3	-1517.385	1.517566	6.19e+30	76.56927	77.16038	76.78300

Notes: (*) indicates the optimal length selected by the criterion
LR: sequential modified LR statistic
FPE: Final prediction error;

AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Authors' estimation

We then run the Doornik-Hansen (2008) multivariate normality test for both VAR models ((ECNeg, RGDPNeg) and (ECPos, RGDPPos)). Tables 7 and 8 present the results of the Doornik-Hansen multivariate normality tests. It can be seen that on both tables the p value for joint normality is significant: this indicates that the residuals are not normal. In addition, ECNeg, RGDPNeg and ECPos do not have a normal distribution property (the p value for the Jarque-Bera statistic is significant). These results indicate that the asymptotic property of the Wald test will be violated if it is used to run an asymmetric causality test between ECNeg and RGDPNeg and between ECPos and RGDPPos. Consequently, we used Hatemi-J's (2012) asymmetric causality test instead of the Wald test to investigate the causal relationship between negative shocks (ECNeg and RGDPNeg) and between positive shocks (ECPos and RGDPPos).

Table 7: Result of Doornik-Hansen multivariate normality test for the VAR model (ECNeg, RGDPNeg)

Variables	Jarque-Bera	df	Prob.
ECNeg	101.1020	2	0.0000
RGDPNeg	17.82731	2	0.0001
Joint	118.9293	4	0.0000

Source: Authors' estimation in eviews 10 based on data from the World Development Indicators (2018)

Table 8: Result of Doornik-Hansen multivariate normality test for the VAR model (ECPos, RGDPPos)

Variables	Jarque-Bera	df	Prob.
ECPos	10.67402	2	0.0048
RGDPPos	0.186097	2	0.9111
Joint	10.86011	4	0.0282

Source: Authors' estimation in eviews 10 based on data from the World Development Indicators (2018)

4.2.3 Result of Hatemi-J (2012) asymmetric causality test applied on both models (ECNeg, RGDPNeg) and (ECPos, RGDPPos)

As said previously, Hatemi-J's (2012) asymmetric causality test is based on a bootstrapping distribution and has superior power and size properties compared to the Wald test which has an asymptotic distribution. It overcomes the limitation of such Wald test in terms of violation of normality property and presence of ARCH effect among the data. There was no ARCH effect among data used in both models (ECNeg, RGDPNeg) and (ECPos, RGDPPos); however, the data used in both models does not have a normal distribution property. All these justified the use of a causality based on a bootstrapping distribution such as Hatemi-J's (2012) asymmetric causality test. The results of this test are presented in Table 8.

Table 9: Hatemi-J (2012) asymmetric causality test results

Direction of Causality	Test value (Wald statistic)	Level of significance	Bootstrapped critical value	Decision
From ECNeg to RGDPNeg	22.883**	1%	23.291	Causality at 5% significance level
		5%	13.275	
		10%	9.630	
From RGDPNeg to ECNeg	11.632**	1%	16.554	Causality at 5% significance level
		5%	11.428	
		10%	8.236	
From ECPos to RGDPPos	0.016	1%	7.556	No causality
		5%	4.258	
		10%	3.005	
From RGDPPos to ECPos	0.750	1%	8.527	No causality
		5%	4.578	
		10%	3.149	

(**) indicates 5% significance level

Source: Authors' estimation using Hatemi-J's (2012) GAUSS code for asymmetric causality, and based on data from the World Development Indicators (2018)

On one hand, we can notice that the estimated Wald statistic is greater than the bootstrapped critical value at 5% significance level for cases of causality from ECNeg to RGDPNeg and from RGDPNeg to ECNeg (see Table 8 above). This indicates that there is bidirectional causality between negative shocks on electricity consumption (ECNeg) and negative shocks on real GDP (RGDPNeg). This result answers our research question which was to verify if negative shocks on electricity consumption have caused negative shocks on economic growth, proxied here by real GDP. Negative shocks on electricity consumption have caused negative shocks on real GDP; therefore we can infer that shortages of electricity have contributed to causing reductions in real GDP in Benin over the period 1971-2014, even though the share of electricity consumption in total primary energy consumption is still very low in the country. According to the World Development Indicators (2017), it is less than 2.07% of total primary energy consumption over the period 1971-

2014. This result also ascertains the conclusions of the national policy framework for electricity (République du Bénin, 2008), which stipulated that shortages or disruptions of electricity supply have been a burden to economic growth in Benin.

On the other hand, it can be seen in Table 8 above that the estimated Wald statistic is lower than the bootstrapped critical values at all levels of significance (1%, 5% and 10%) for cases of causality from ECPos to RGDPPos and from RGDPPos to ECPos. This indicates that there is no causality between positive shocks on electricity consumption (ECPos) and positive shocks on real GDP (RGDPPos). This result aligns with the historical fact of the Beninese context where, according to the World Development Indicators (2017), the share of total electricity consumption has remained less than 2.07% of total primary energy consumption over 44 years (1971-2014) and the highest rate of access to electricity in the country over the period 1990-2016 was 41.40%. In other words, over the period 1990-2016, less than 50% of the population had access to electricity. Electricity consumption is still very low in Benin and has not yet reached the threshold at which it can begin to cause a positive shock on economic growth. Positive shocks on economic growth do not cause positive shocks on electricity consumption although electricity is used in different sectors of the economy such as the service sector, the industrial sector and the residential sector (households' use of electricity is classified as the residential sector's use of electricity or residential electricity consumption).

4.2.4 Result of Hacker and Hatemi-J's (2006) symmetric bootstrapped causality test

While the aim of this study is not to investigate the causal relationship between electricity consumption and economic growth using a symmetric approach, the results of the symmetric causality between these two variables is presented in Table 9 below in order to confirm the importance of applying an asymmetric approach. Table 9 shows that there is no symmetric causal relationship between electricity consumption and economic growth. This result does not allow us to understand the causal effect of negative shocks on both variables, nor does it allow us to understand the causal effect of positive shocks on both variables. Based on the symmetric approach we cannot understand that there is bidirectional causality between negative shocks on electricity consumption and negative shocks on economic growth, while there is no causal relationship between positive shocks on electricity consumption and positive shocks on economic growth. All these highlight the limitation of the symmetric approach, and confirm the complexity of channels through which economic growth and electricity/energy consumption influence each other and the necessity of applying an asymmetric approach.

Table 10: Results of Hacker and Hatemi-J's (2006) symmetric bootstrapped causality test

Direction of Causality	Test value	Level of significance	Critical value	Decision
From EC to RGDP	0.017	1%	7.062	No causality

		5%	3.954	
		10%	2.646	
From EC to RGDP	0.752	1%	8.494	No causality
		5%	4.999	
		10%	3.326	

Source: Authors' estimation using Hatemi-J's (2012)s GAUSS code for symmetric causality

The aim of this study is to verify if negative shocks on electricity consumption have caused negative shocks on real GDP in Benin over the period (1971-2014). Hence, the discussion and policy recommendations will focus on this.

5 DISCUSSION AND POLICY IMPLICATIONS

This study has demonstrated that negative shocks on electricity consumption have caused negative shocks on real GDP in Benin. In other words, disruptions of electricity in Benin have been a burden on the economy and caused reductions in real GDP. As said previously, this study has ascertained the conclusions of the national policy framework for electricity (République du Bénin, 2008) stipulating that shortages of electricity have caused reduction of economic growth. The results of this study highlight the importance of electricity security in Benin. It is important for the country to ensure its electricity security as disruptions of electricity have caused reductions in economic growth.

Until recently (2015), Benin imported 77.575% of its electricity supply. As said previously, dependency on importation of electricity and losses of electricity have been major causes of electricity disruptions. Dependency on importation of electricity from neighbouring countries such as Ghana resulted in major disruptions of electricity in Benin in the 1980s, 1990s and 2000s and has been a burden on the economy (République du Bénin, 2008; US EIA, 2018). It is therefore important for Benin to reduce its dependency on importation of electricity by increasing its self-sufficiency rate of electricity supply. The national policy framework for electricity has targeted to increase self-sufficiency rate of the electricity supply to 70% by 2025 (see République du Bénin, 2008, pp. 54, 56). Losses of electricity caused a reduction in the available quantity of electricity that is supplied to consumers, and they also constitute a burden on the economy. The national policy framework for electricity has targeted to reduce losses of electricity to 14% from 2020 to 2025 (see République du Bénin, 2008, pp. 38, 41). Results of this study emphasize the importance of these policy decisions concerning the self-sufficiency rate of electricity supply and reduction of losses of electricity. Dependency on importation of electricity and electricity losses are disruption risks to electricity, which have led to negative shocks on electricity consumption, while negative shocks on electricity consumption have caused negative shocks on real GDP over the period 1971-2014.

This result aligns with some of the few studies which have established that negative shocks on total energy/disaggregated energy consumption cause negative shocks on economic growth. Significant among these few studies are Ranjbar et al. (2017) on South Africa, Tiwari (2014) on the US economy, Hatemi-J and Uddin (2012) on the US economy, Bayat et al. (2017) on Turkey, Shahbaz et al. (2017) on India, and Destek (2016) on India. However, throughout the empirical literature on asymmetric causal relationship between economic growth and energy consumption, no study (to the best of the writers' knowledge) has investigated if negative shocks on electricity consumption cause negative shocks on economic growth in the Beninese context. This study has filled this gap, and is a contribution to the existing literature on electricity security and economic growth in general, and particularly to the existing literature on disruptions of electricity and economic growth. This study will be of great importance for the current debate and formulation of electricity security policy in Benin where disruption of the electricity supply is a major concern.

6 CONCLUSIONS AND RECOMMENDATIONS

This study has fundamentally established that negative shocks on electricity consumption have caused negative shocks on economic growth in Benin, although the World Development Indicators (2018) reported that electricity consumption is very low in the country, compared to biomass or oil consumption. This study has ascertained the conclusions of the national policy framework for electricity stipulating that shortages of electricity have impeded economic growth in Benin. To the best of the writers' knowledge, until this study no empirical evidence had verified such conclusions. Through such verification, the current study has proved that shortages of electricity negatively affect economic growth and this emphasizes the importance of electricity security policies, which aim to reduce disruption of the electricity supply in Benin. Some of these electricity security policies have been formulated in the national policy framework for electricity in terms of targets for the self-sufficiency rate and the efficiency rate of electricity supply. As reported by the Republic of Benin (République du Bénin, 2008), the national policy framework for electricity aims to increase the self-sufficiency rate of electricity supply by 70% in 2025 and targets to reduce electricity losses to 14% from 2020 to 2025. The current study emphasizes the great importance of these policy decisions for electricity security in general and particularly for disruption of the electricity supply in Benin. Although electricity consumption is very low in Benin, the country should not allow disruptions of electricity, as they constitute a heavy burden for economic growth.

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