Key Factors of Demand for Energy within the ECOWAS Zone

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Abstract

In this paper, using an error correction model, we try to estimate the relationship between energy demand and its key factors in the ECOWAS zone based on sample data of six member States covering the 1975 – 2005 period. We calculate long and short-term elasticities of energy demand, and demonstrate that at regional level only the long-term impacts of the effects of agricultural and industrial structures are significant, while income impacts negatively on energy demand both in the long and short terms. Thus, agricultural or industrial variations generate similar variations in energy demand, albeit to a less extent. Per capita income variation has the opposite effect on energy demand that is twice insignificant in the short than in the long term. Avenues have been suggested to allow for an efficient and environmentally-friendly regional policy.

1. Introduction

The complex relationship between energy consumption and its key factors have received little attention in West Africa in recent years, even though there is unanimity that they must be understood in order to adopt efficient regional energy policies as required by the community authorities. This need has intensified lately with the sub-region's recurrent energy crises and rising energy prices in general, and oil prices, in particular.

Given the substantial increases in world oil prices over the past few years, an analysis of energy demand has become a major policy issue. Many energy efficiency indicators have been developed and applied to explain the energy performance variations from one country to another, and to conduct an international comparison of such performance. The elasticities of energy demand are answers often found in energy studies conducted in the 1970s and 1980s (Destais et al., 2007).

Kraft and Kraft, (1978), Yu and Choi, (1985), Erol and Yu (1987), Masih and Masih (1996, 1998), Asafu-Adjaye (2000) and more recently Fatai et al (2004), Lee (2005), Al Ariani (2006), Mahadevan and Asafu (2006) have

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shown some correlation between economic growth and energy consumption. According to Percebois (2000), we perceive this correlation as an undeniable premise, such that seeking to reduce energy consumption per capita or per production unit is considered by many as undermining social well-being. However, according to Peccei, (1976) "*all the problems in agriculture, raw materials and energy boil down to the idea of wastage."* This idea of wastage is strengthened by the fact that the quantity of primary energy needed to produce one franc of Gross Domestic Product varies not only from one country to another, but also from year to year in the same country.

At best, these studies have shown the causality relation between economic growth and energy consumption in developed countries, and some developing countries. In some cases, the country sample included some ECOWAS member countries, but the analyses focused primarily on highlighting the meaning of this GDP-growth causality. Some studies have focused on specific countries in West Africa; for example, Gbaguidi (2001) identified the key factors of energy demand in Benin. The study, like most others based on national chronological studies, encountered difficulties arising from strong elasticities whose relatively limited scope is due to problems of routine statistics in DCs. The panel estimate at ECOWAS level seems to be a solution to the problem.

This analysis will use recent techniques of panel data econometrics to work out an energy demand function at regional level, and while underscoring country specificities. First of all, the methodological aspects of the analyses will be considered. Subsequently, empirical results will be presented, leading to policy conclusions and recommendations.

2. Data and Method

2.1. Measuring Variables and Data Sources

The study uses data from the World Bank's 2007 version of African Development Indicators, covering the 1975-2005 period. This choice is dictated by data available at country level on energy consumption and by the concern to have a panel without any missing data. The same applies to the number of countries studied. Indeed, only six out of the fifteen ECOWAS member States have statistics on energy consumption in this database. For the regional analysis, a sample of countries is used, namely Benin, Cote d'Ivoire, Ghana, Nigeria, Senegal and Togo. In this group, various country categories can be distinguished: energy exporting countries because they export oil and electricity (Nigeria and Cote d'Ivoire), electricity exporters and oil importers (Ghana and Cote d'Ivoire), oil and electricity importing countries (Benin, Togo, Guinea, Gambia, Senegal, Niger), etc. This sample focuses also on countries that drive economic growth in the sub-region: Nigeria, Senegal and Côte d'Ivoire. In addition, Nigeria accounts for about 98% of proven oil and natural gas reserves, and alongside Ghana and Côte d'Ivoire, is one of the five countries (with Guinea and Sierra Leone) that have 91% of the sub-region's hydro-electric potential (Diaw, 2004). The sample can therefore be considered as fairly realistic.

The commercial gross domestic product and value added in dollars were used. Energy consumption refers to consumption of primary energy, and is equivalent to domestic production plus exports and stock variations, less exports and the consumption of fuel used for international sea and air transport. It therefore also includes the consumption of energy prior to processing for various uses (electricity, by-products of refined, etc.) as well as the consumption of power produced by renewable energies or waste. The data on the various forms of energy are converted into the oil equivalent in the database. Energy intensity is deduced from the two previous variables (GDP and Energy Consumption) comprising it.

The Agvalu and Indvalu variables are respective portions of the value added of the primary and secondary sectors in the gross domestic product. The sectoral value added was compared to the overall value added to give the value added portions as follows:

$$\text{Agvalu} = \frac{VAprim}{VAtot} \text{ and Indvalu} = \frac{VA\text{sec}}{VAtot}$$

VAprim, VAsec and VAtot being the value added of the primary sector, the value added of the secondary sector and the value added of all three sectors of the economy respectively.

The consumer price index was used as proxy of the energy prices, as in Mahadevan and Asafu-Adjaye (2006, op.cit.). This choice is due to lack of country data on the energy price index in the sub-region. An alternative approach would be to use the annual average prices of crude oil covering the study period, but this option could result in a series of data for a single price vector for all individuals. This will create problems in the econometric estimate of the model, and will be difficult to justify in the price policy of the various countries. Indeed, most States in the sub-region implement a policy of administration of pump oil product prices, which implies, at least for a long time, that there were no clear links between crude oil prices and the actual prices. Although in most cases this policy has led to some improvement in that the prices undergo monthly variations that somehow reflect the realities of the international commodity market and are too recent for identification of a chronological series that can be used in this study.

2.2. Specification of the Energy Demand Model

There are several energy demand models in economic literature. Depending on the techniques used, there are Calculable General Balance Models (CGBM), the trend forecasts model, and traditional econometric models.

The CGBMs are detailed macro-economic models with microeconomic bases that make it possible to rigorously determine the pattern of the supply and demand functions by maximizing the behavior of household utility functions, as those of corporate profit. They allow for a study of the impact of economic policies on energy demand as well as on the environment. Although these highly detailed models have the advantage of being consistent in formalizing all simultaneities, they cannot, however, be calculated only in concrete situations using traditional methods (Villa, 2000). Indeed, the calculable general balance models are like the Walrasian balance and are calibrated over a given period rather than estimated. However, they allow for long-term forecasts with key external variables such as population growth, total productivity factors and fiscal and budgetary policies. These models were developed by Beaver and Huntington (1992), Beaver (1993) and Bhattacharyya (1996)[2].

These long-term generic energy intensive forecast models can be grouped into three categories: estimates according to logistic function models, the so-called learning models, and the Translog models.

Futardo and Suslick estimated the trend using a logistic function (1993) to project the intensity of oil consumption against the GDP in Brazil, as did Hourcade (1993) to develop macro-economic scenarios. The method consists in assuming that the energy intensities follow a logistic law with an asymptomatic saturation threshold modulated by economic components such as prices and income. "*However, the relevance of the models used is doubtful, because energy intensities very often show U or staircase curves rather than saturation levels"* (Villa, op.cit., p.18). Moreover, the proponents of the method never make an estimate of the entire model and do not ask whether the factors that determine the energy intensity growth rate are different from those of a possible saturation level. Villa (op.cit.) shows that it is possible to find an approach that searches for trends while maintaining the usual economic factors. By making the growth rate of relative prices, income and outlook variables interdependent, and by assuming that the asymptote depends on the wealth per capita and of the population or its density, we have:

$$\frac{\Delta e_t}{e_{t-1}(a(POP,W)-e_{t-1})} = b[(PIB_t)TU_t,\Delta(PR_t)]$$

e_t being the primary energy intensity, POP the population, W per capital wealth, TU the capacity utilization rate and PR relative prices, GDP the GDP in volume, Δ is the initial difference operator. This formulation shows that the search for a trend and the usual economic factors can be combined.

The Futardo and Suslick learning models assume that the trend is the result of an adaptive process. Thus, the energy intensity expectations are revised in light of past econometric information, which precludes some infor-

2. These authors were quoted by Villa (2000)

mation from the projection period. More specifically, it is assumed that the econometrist was able to observe over the period [1,T], the primary energy consumption E_t (in Tep), the GDP, Y_t in volume and therefore the energy intensity from these two variables ($e_t = E_t / Y_t$). But the real energy intensity model consists in a linear connection of Log (e_t) to Log (Y_t), other Z_t variables and the constant. If it were possible to observe Z_t, it could be estimated econometrically. The modeller may then envisage a learning process that leads to the true model. In the final analysis, the method does not lead to good energy demand forecasts. "*Nonetheless, again, there is no real agent behavior since the learning process in question concerns only the modeller" (Villa, op.cit., p.19).*

The Translog models are based on long-term statistic observation according to which the energy intensity may be described in the long term using a normal log-type curve with a sharp skewness depending on the per capita income (Villa, op.cit.). If Futardo and Suslick's estimates for oil demand in Brazil based on this method show good results, they have the disadvantage of assuming that price elasticity increases with per capita income. Hence, the difficulty in applying this method to aggregate data such as those used in this study.

The last major model category used to analyze energy demand is made up of econometric models. There are models that take into account the general factors of the demand theory and models with price expectations. The most representative of the first group of models is that of Houthakker and Taylor. They introduce into the analysis the stock and flow factors of final consumption which helps to theoretically distinguish the short and long terms. The premise is that energy demand depends on the overall expenditure, relative prices and a status variable which is by and large the stock of the previous period. Vallet (1978) quoted by Villa (op.cit.) has made estimates of a function of this type for domestic energy and fuel demand by the households. The findings show strong instability of all the coefficients. The method also implicitly presupposes that elasticities are variable over time, but that their trends are highly dependent on relative prices. According to Villa (op.cit., p.25) the model is also under determined because "*long-term arguments should be found for stock variable, for instance population, total wealth, the accommodation (heating) or the vehicle fleet (fuel).* Furthermore, an estimate in logarithm rather than in level or propensity should correct the residual heteroskedasticity while promoting direct elasticity estimates. As regards elasticities, the model implicitly presupposes that they are variable over time but that their trends are highly influenced by that of relative prices. As for the price anticipation model, they base their argument on the premise that energy demand did not respond to the price decline of the 60s in a manner symmetrical to the price increase of 1974 and 1980. Energy consumption would depend therefore, according to the proponents of this approach, on anticipated income and anticipated relative prices, since expectations could be rational or myopic. Using such a model therefore implies making expectation assumptions. Wirl's

(1991)[3] application of both assumptions alternatively to French data led to significantly equal price and income elasticity. However, the assumption of the existence of rational price and income expectation, which was supposed to lead to positive implicit verifiable discount rate led to a negative rate; this implies that the expectations are not rational. Some authors have added to these two variables (anticipated income and anticipated price) the real interest rate for energy so as to take into account the inter-temporal dimension. The estimates made by Kauffman (1994) led to the conclusion that price elasticities are due mainly to the phenomena of substitution between energies rather than substitutions between factors or between energy and other consumables. These estimates are based on the premise whereby price expectations are neither myopic nor rational, but are based on price forecasts of institutional organizations. Thus, contrary to Wirl, instead of making assumptions on the nature of anticipations, we must measure them, and then determine their impact on energy demand using an econometric model. Despite uncertainties stemming from measuring expected income and prices, these models have the advantage that they can be estimated not only by businesses but also by households. For companies, we use a general KLE (capital, labor, energy) inter-temporal production model, and we make assumptions on the type of technology used by the companies (putty-putty, clay-clay or putty-clay). However, our objective is not to study the energy demand specific to each type of user (households, companies); we shall not use that method. Moreover, the key factors of the consumer price of energy in the sub-region make it difficult to take into account myopic or rational expectations.

Overall, the energy demand estimates show that the Houthakker-Taylor model is robust. On the whole, the income effect is very close to one, whereas it is somewhat difficult to estimate the price effects, either because of economic phenomena or for statistic reasons. These statistical problems could be avoided if the equations in question are evaluated using the co- integration method. The estimates have also shown that energy price expectations do not seem to have an impact on demand. Consequently, it would be better to evaluate a neo-Keynesian method that distinguishes between energy price elasticity and other substitution goods, and which introduces delays rather than seek to evaluate an inter-temporal model with rational expectations. That is why we have chosen the following model:

$$Ldemen_{it} = \alpha_{1i} + \alpha_{2i}\ Lagvalu_{it} + \alpha_{3i}\ Lindvalu_{it} + \alpha_{4i}\ a4\ Lpitet_{it} + \alpha_{5i}\ Lprix_{it} \quad (1),$$

Here Ldmen refers to the logarithm of energy demand, Lpitet the logarithm of real per capita GDP, Lagvalu and Lindvalu, the logarithm from the value added of the primary and secondary sectors respectively in the total value added. Lprice refers to the logarithm of the consumer price index, the proximal energy price.

3. Quoted by Villa (op.cit.)

We expect that α_2 and α_3 will be positive signs because one can reasonably assume that energy demand evolves in the same way as the activity level in each of these production sectors; whether positive or negative, and depending whether the income elasticity of energy demand is higher or lower and that α_5 is negative.

2.3. Estimation Methods

2.3.1. Unit Root Test

Recent developments in the literature suggest that unit root tests on panel data are stronger than tests on individual chronological series.

Tests were developed recently by Breitung (2000), the Hadri test (2000), the Levin and lin test (2002) and the Im Pesaran and Shin test (2003)

Two test categories can be distinguished: the first generation tests, which imply inter-individual residual independence, and the second generation tests, which raise this extremely restrictive assumption and which, according to Hulin and Mignon (2005), is particularly awkward in most macro-economic applications.

The Livin and Lin (LL) test draws directly from the unit root tests on Dickey and Fuller's (1974) temporal series. Applying the homogeneity assumption of the auto regressive root, this test considers the unit root assumption for all panel individuals null against the hypothesis of the lack of unit root for all individuals. In such conditions, it is unlikely that in the event of rejection of the null hypothesis, we can accept the auto-regressive root common to all individuals.

The test proposed by Im, Pesaran and Shin (1997, 2002, and 2003) satisfies this concern. Im, Pesaran and Shin (IPS) consider a model with individual effects and without the determinist trend. Like Levin and Lin, they postulate the unit root against the possibility, on the other hand, of the cohabitation of two categories of individuals in the panel: those individuals for whom the variable is stationary and those for whom it is not. Hurlin and Mignon (2005) have, in addition to the advantage of the IPS which takes heterogeneity into account, identified that of proposing simple statistics based on the mean of the DF or ADF stat.

Maddala and Wu (1999) propose a Fisher non-parametric test based on a combination of individual n test significance levels. Maddala and Wu have shown, through a series of experiments, that their test is more powerful than the IPS test similar to it.

To these three tests, which seem to be the most used despite their weaknesses, should be added that of Hadri (2000) which makes the null assumption of stationarity against the unit root alternative. It has the advantage of not requiring any model specification even though it needs a relatively large size (T and N important).

2.3.2. Cointegration Test

The literature on panel cointegration tests is recent and is developing very rapidly. Hurlin and Mignon (2007) have presented a detailed paper on various tests.

The first set of co integration tests on the panel data residual models is based on the null hypothesis of no co-integration as suggested in the literature of chronological series (see McCoskey and Kao (1998)). There are two cases: the first assumes that the variable coefficients are common to all panel members, and the second that the coefficients are different. We thus arrive at the hypothesis of panel heterogeneity.

Kao (1999) suggests testing the presence of cointegration using an ADF type test. It presents the fallacious regression model in the panel data and examines the asymptotic properties of the least squares with dummy variables. It also presents panel cointegration tests based on regression residuals. The particularity of this model is that it tests the presence of cointegration for every cross section of the panel using the hypothesis of group independence.

The ADF test is built from the regression of differential residuals. The null cointegration absence assumption for each value of i, is evaluated by the average of the individual ADF tests.

An alternative approach has been developed by Pedroni (1997, 1999) who draws on the average cross-section of statistics of Philips and Ouliaris (1990). Pedroni gives seven statistics tests to test the null hypothesis of no-cointegration in the data panel.

Many studies based on these various tests could not reject the hypothesis of absence of cointegration even though cointegration between variables is strongly recommended in economic theory. One of the reasons for this difficulty is that these cointegration tests, both on individual data and on a residual based panel, demand that the long-term parameters of the variables be equal to the short-term parameters of the different variables. Banerjee et al. (1998) and Kremer et al. (1992) consider that as a restrictive factor, and have shown that this weakness can cause a significant power loss in the residual cointegration tests.

In response to this criticism, Westerlund (2007) developed four new cointegration tests that are based not on the residuals but on the structural dynamics of relations, and which consequently do not impose any restriction on common factors. The idea of testing the null hypothesis of no cointegration by verifying whether the error correction term in the error correction model built for that purpose is significantly equal to zero. The four tests are normally distributed and fairly well accommodate the short-term individual dynamics, the trends and parameters specific to individuals and intra-individual dependence. The first two tests make it possible to test the no integration null hypothesis against the alternative hypothesis according to which the panel as a whole is cointegrated, whereas the last two tests test the alternative existence of at least one individual for which the variables are co-integrated.

We are adopting the cointegration test to experiment on the existence of a long-term relation between energy demand and its key factors in our panel. For more details, see Westerlund (2007) for the description of the Persyn and Westerlund test (2008) for implementation using stata. Persyn (2008) developed a stata module which can be used in implementing the Westerlund tests.

3. Empirical Results

3.1. Unit Root Test

The Augmented Dickey-Fuller Unit Root Test (ADF) was tested on individual data (Table 1). The delays were optimized by the Hanan and Schwatz criterion. The findings suggest that energy demand and per capita income are integrated by order 1 for all countries except Nigeria for which they were integrated by order 2. The structure effect linked to the industrial sector is integrated by order 1 for all countries in the panel. The structure effect relating to agriculture is integrated by order 1 for all countries except Côte d'Ivoire for which this variable is integrated by order 2. As for the price variable, it is integrated by order 1 for all countries and integrated by order 2 for Senegal and Togo.

Several authors, including Hadri (1999), Hall and Urga (1999), have discovered that the power of these tests on level series and on cointegrating regression residual is weak, but by using a much richer data source such as panel data, we obtain more powerful tests against the appropriate alternative hypotheses. The LL, IPS and Fisher test results are shown in Table 2.

For the six variables, the unit root absence null hypothesis could not be rejected in terms of level. In the first difference, this hypothesis is rejected for all the variables of the analysis. Besides, the Fisher test confirms most of these results, whereas the LL test gives mitigating results. To conclude, the panel series are all integrated by order 1.

3.2. Cointegration Test

3.2.1. On Individual Data

The Johannsen cointegration test carried out on each country reveals the existence of at least a cointegration relationship between the variables of the model. By virtue of Granger's representation theorem, this implies the existence of an error correction model to highlight both the long and short-term dynamics at country level between the energy demand key factors.

Table 1. *Unit Root Test on Individual Variables*

	Ldemen			Lagvalu			Lindvalu			Lpitet			Lprice		
	Lev	Lag	D	Niv	Lag	D	Niv	Lag	D	Niv	Lag	D	Niv	Lag	D
Benin	-2.162	1	-3.90***	-2.01	1	-3.15*	-3.43*	2	-3.55**	-1.74	3	-4.36***	-1.51	1	-3.20*
Cote d'Ivoire	-2.37	1	-3.40*	-1.84	2	-2.91	-1.91	1	-4.23***	-2.48	2	-3.62**	-1.45	1	-3.24*
Ghana	-2.19	1	-3.46*	-2.54	4	-4.86***	-2.59	3	-4.30***	-1.48	1	-3.07*	-0.45	1	-3.23*
Nigeria	-1.21	1	-2.98	-2.49	3	-4.46***	-2.52	3	-4.14***	-1.52	2	-2.99	-2.21	4	-3.23*
Senegal	-2.65	1	-4.28***	-1.78	1	-5.14***	-1.82	1	-4.30***	-1.17	2	-5.34***	-1.72	1	-2.96
Togo	-2.706	1	-4.18***	-3.16*	3	-4.93***	-2.11	2	-3.73***	-2.34	1	-3.82***	-2.26	1	-2.97

Source: Our estimates (2008)
(***), (**) and (*) that the corresponding null hypothesis may be rejected respectively at 1%), 5% or 10%. (D) indicated the first difference operator.

Table 2. *Unit Root Tests on Variables in Panel Data*

Variables	Levine Lin		IPS		Fisher	
	Constant	Constant and Trend	Constant	Constant and Trend	Constant	Constant and Trend
Ldemen	-0.0962	-0.1589	-1.251	-1.643	21.79**	23.42**
Lagvalu	-0.2514	-0.5602	-1.949	-2.773**	14.33	20.02*
Lindvalu	-0.1985	-0.4242	-1.850	-2.415	23.94**	4.80
Lpitet	-0.0707	-0.3230	-1.116	-2.344	7.44	7.89
Lprix	-0.0314	-0.1674	-1.690	-2.198	9.82	37.30***
DLdemen	0.9874	-1.1093	-2.903***	-3.118***	37.30***	20.80**
DLagvalu	-1.3885**	-1.4135	-3.703***	-3.667***	62.24***	40.21***
DLindvalu	-1.0442***	-1.0844	-3.122***	-3.136***	30.06***	29.33***
Dlpitet	-0.8390	-0.9163	-2.747***	-2.853**	29.56***	29.33**
Dlprix	-0.6010	-0.8811	-2.568***	-2.887**	22.71**	15.88

Source: Our estimates (2008)
(***), (**) and (*) show that the corresponding null hypothesis may be rejected at 1%, 5% or 10% respectively. (D) indicates the first difference operator.

Table 3. ***Results of the Westerlund Panel Tests***

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-2.157	-1.071	0.142	0.100
Ga	6.813	0.391	0.652	0.090
Pt	5.187	1.496	0.067	0.040
Pa	6.250	0.768	0.221	0.050

Source: Our estimates, 2008; Bootstrapping critical values under H0.........., Calculating Westerlund ECM panel co integration tests......, Results for H0: no co integration

Thus, there is a long-term relationship between the key factors of energy demand in each country of the sample. What about the panel?

3.2.2. Panel Cointegration Test

The Persyn and Westerlund Cointegration Test (2008) was conducted on the series in two phases. In the first phase, the test could not reject the null hypothesis. The second phase, which controls the auto error correlation by making a bootstrap critical value to obtain robust statistics, led to the results summarized in Table 3. These results suggest that the no cointegration hypothesis can be rejected at the 10% threshold for the first two series of Westerlund statistics (Gt and Ga) and at the 5% threshold for the last series of statistics.

In conclusion, the energy demand, the two structural effects, prices and income are variables that maintain a long-term relationship in ECOWAS countries. This suggests the relevance of an error correction model to highlight the relations between the energy demand of ECOWAS countries and its key factors.

3.3. Specification Test of Individual Effects

Using the Hausman test, we can accept the null hypothesis whereby the effects specific to each country may be correlated with the variables of the model or, alternatively, that these effects are orthogonal at these explanatory variables. In other words, the Hausman test helps us to choose between the fixed effect model (1) and the risky effect model== (2).

$$Ldemen_{it} = \alpha_{1i} + \alpha_2 \, Lagvalu_{it} + \alpha_3 \, Lindvalu_{it} + \alpha_4 \, Lpitet_{it} + \alpha_5 Lprix_{it} \; \varepsilon_{it} it \quad (1)$$

$$Ldemen_{it} = \alpha_{1i} + \alpha_{2i} \, Lagvalu_{it} + \alpha_{3i} \, Lindvalu_{it} + \alpha_{4i} \, Lpitet_{it} + \alpha_{5i} \, Lprix_{it} + \varepsilon_{it} \quad (2)$$

The Chi2 statistics associated to the Hausman test (cf annex) show a value of 9.80 with a probability value below 5%. This means that the individual effects exist, and may be appropriately considered as fixed effects.

The model adopted in the rest of the analysis will be model (1)

3.4. Auto error correlation test and the intra individual heteroskedasticity test

We carried out the Wooldrigde auto correlation test (2002)[4]. This test, under the sub-STATA xtserial name, lays down as first order, the absence of null hypothesis residual auto correlation. It has the advantage in comparison with other tests (pantest2) of not imposing a choice between a fixed effect and a risky effect model.

Therefore, we note (Prob>F=0,0004), a rejection of the null hypothesis, which implies that the errors are correlated.

The Wooldridge test carried out on the panel allows a rejection of the first order auto-correlation absence hypothesis (F(1, 5) = 68.202 avec Prob > F = 0.0004

This result of a first order auto correlation between the residuals is confirmed by the auto-correlation test (pantest2), based on the previous choice of the fixed effect module. The Breusch Pagan test show that the error variance is not constant for all individuals (Pr=0,0000). Intra-individual heteroskedasticity can therefore be seen.

3.5. Energy Demand and its Key Factors

The existence of at least a cointegration relationship between variables, all order 1 integrated, imposes the implementation of an error correction model to evaluate energy demand both at regional and country levels.

Based on the corresponding literature, the error correction model equivalent to the demand function (1) can be illustrated as follows:

$$DLdemen_{it} = \beta_1 DLagvalu_t + \beta_2 DLindvalu_t + \beta_3 DLpitet_{it} + \beta_4 DLprix_{it} + \mu_1 Lagvalu_{it} + \mu_2 Lindvalu_{it} + \mu_3 Lpitet_{it-1} + \mu_4 Lprix_{it-1} + \gamma\, Ldemen_{it-1} + \varepsilon_{it} \quad (3)$$

In these conditions, β_j represents short-term elasticities whereas ratios $\mu_{j/}\gamma$ represent short- term elasticities, γ being the error correction term, whose negativity and statistical significance validate the error correction model. The various elasticities are shown in Table 4. The estimates were made under stata 8 taking into account both the heteroskedasticity and the residual auto correlation.

The various error correction terms (ECT) are negative and significant at least at 10% (Ghana and Togo) and at 1% for the other countries of the region.

The results indicate that at regional level energy demand can be explained to a great extent by most of the key factors identified; in this case the two structural effects (agriculture and industry) and income. The relationship

4. Wooldrigde, 2002, STATA Journal (2003), Volume 3, issue 2

Table 4. ***Estimate of the Individual Demand Function and the ECOWAS Demand Function***

	Lagvalu		Lindvalu		Lpitet		Lprix		ECT
	CT	LT	CT	LT	CT	LT	CT	LT	D
Benin	0.196	-0.622	0.722***	-2.10**	-0.508	-2.358	0.306	2.73	-0.272***
C. Ivoire	-0.78**	-0.491	-0.633***	0.956	0.347	0.753	-0.016	0.127	-0.509***
Ghana	-0.86*	-1.579	-0.08	0.020	-0.76	0.162	-0.064	-0.974	-0.468*
Nigeria	0.176	2.421**	-0.241	1.654*	-1.125	-2.606*	0.211	-0.078***	-0.318***
Senegal	-0.268	-0.128	-0.891	-1.101	1	-0.036	0.753	-0.064	-0.356***
Togo	-0.114	0.891	0.053	-1	-1.29***	-0.753	0.711	-0.118	-0.304*
ECOWAS	0.04	1.304***	0.76	1.09***	-0.52***	-1.07***	-0.06	-0.011	-0.327***

Source: Our calculations, 2008

with price is not significant, even though taking this variable into account in the model improves the overall significance.

The impact of these various key factors that influence energy demand at regional level is much more significant in the long term. Indeed, the long-term elasticities show statistics significance of up to 1% against a non-proven significativity for short-term elasticities.

Thus in the short term, the structure effect exercised by the agricultural sector on regional energy demand is quite insignificant. This effect is not null in so far as the Wald test did not make it possible to eliminate this variable of the error correction model. It is, however, significant for Côte d'Ivoire and Ghana.

In the long term, whereas at country level this agricultural structural effect is virtually inexistent, it is highly significant at regional level. Thus, when the agricultural share in the total value added increases in the long term, energy demand increases much faster (Elasticity =1,304). In comparison, we see that Villa (2000) on pre-Second World War data showed that the structural effect at the primary sector level is important both in the long and short terms but in the reverse. In other words, pre-war data indicates that a decrease in the agricultural value added generates an increase in energy demand. However, post-war data indicates the opposite effects. Kaufmann (1994), on American data, has obtained the structural effect for the primary sector even weaker than the latter, that is – 0.097, or an energy demand even less sensitive to structural effects due to the agricultural sector than the energy demand evaluated for the West African sub-region. The only studies available on developing countries, at least to our knowledge, emphasize primarily the relationships between energy demand and income, as well as price when it is available, thus making it difficult to compare our results to those of other countries with comparable development levels. Indeed, the French situation prior to the Second World War cannot validly be compared with that of the West African sub-region in terms of development level of consumer behavior. These elasticities, however, have the advantage of giving an order of magnitude of value found in previous studies.

At regional level, changes in the industrial fabric significantly affect energy demand only in the long term. The only country specificities appear only for Benin and Côte d'Ivoire where the short-term effect is fairly significant. Thus, an increase in the industrial value added in the total value added positively affects regional energy demand in the long term and in a virtually proportional manner.

This result, which meets expectations, is contrary to those obtained by Gbaguidi [5](2001) for Benin, and is far from the conclusions of Kaufmann (op.cit.) who obtained a null structure effect for the American industrial sector, and of Villa (op.cit) who obtained a non-significant effect for France.

The energy demand is sensitive to income both in the short and long terms. Indeed, the income elasticities are all significant to the 1% threshold. In the short term, an increase of 1% in the per capita income leads, all things being equal, to a half point decrease in energy demand (-0.52), while the long-term energy demand will decrease virtually in the same proportion as the per capital income (long term elasticity = -1.07). In comparison, only a long-term significant influence could be highlighted with an elasticity of about -1.15. For France, the income elasticity was estimated in the short term at around – 0.26 and in the long term at a value higher than the unit; these estimates were made on data from the period before and after the two wars. For the United States, Kauffmann did not calculate the income elasticities because his energy demand model, more specifically the oil demand, does not fall under income as an explanatory factor.

Energy demand is therefore much more sensitive to long-term than short-term wealth. The higher the per capita income, the lower the energy demand. This result can only be understood if one bears in mind that the national energy demand is calculated in terms of energy intensity. The higher the per capita income, the more the resources of economic operators to acquire low energy consumption technologies but at a high purchase price[6]. This explains why the quantity of energy necessary to produce a GDP unit is decreasing: "*developing countries have limited access to energy and the use they make of it is often less efficient than industrialized countries*" (Percebois, 2001, p.16.). A study conducted by the European Commission published in 1996 shows that in 1990 the energy intensity was 302 tep by MECU 1985 with the OECD, against 415 in Latin America, 545 in Africa, and 926 in Asia, an energy intensity which decreases depending on per capita income. We also see that as income increases, the tendency to substitute one form of energy for the other seems increasingly strong. This can be explained by the high cost of equipment needed to make these changes, leading to a more economical use of energy. Households can thus go from firewood to gas or electricity, from

5. This study arrived at an short term elasticity of -0,1982
6. An economic lamp costs for instance in the informal market where most households buy them, costs seven to eight times more than fluorescent lamps.

lamp oil to gas, to electricity, etc, defraying more easily the new expenses thanks to higher income.

Energy prices or, more specifically, the proxy consumer price index do not have a significant effect on energy demand at sub-regional level. At least not more than one statistically significant link between the two variables was highlighted in the long term in the case of Nigeria. Since this variable is of utmost importance in a demand model, it seems difficult to envisage a demand function without this argument, which should maintain a negative relationship with the demand. The proxy thus shows all its limitations, even though the sub-region has no other alternative currently in terms of statistics for a reliable energy price index. Also under scrutiny is the price policy practised by all the countries in the sub-region up until quite recently. Indeed, a price control policy and a high pump price subsidy have always co-existed so as to mitigate the impact of international price fluctuations on the consumer's purchasing power.

4. Conclusion and Recommendations

4.1. Conclusion

Although this study has highlighted certain key factors of energy demand in the ECOWAS space, it is nonetheless true that other factors may have escaped analysis. The issue of price, for example, is yet to be determined. The high sensitivity of oil prices in the informal sector, in the countries where they exist, already indicate that a significant proportion of energy demand is satisfied by supply that functions virtually according to the law of supply and demand[7]. Taking that dimension into account could help determine the impact of prices on energy demand.

Disregarding the issue of energy prices in the demand model also raises the problem of substitution between energy and the other factors, on the one hand, and between the various forms of energy, on the other. The constraint of non-availability of disaggregated data on enterprises and households, as well as on the various forms of energy made it impossible to conduct our analysis in that direction, which should be of great interest for knowledge on energy demand in its micro-economic dimension, thus in its more interesting dimension for working out energy policies in an inter-generational logic. Taking into account other variables such as real interest rate in relation to energy (to take into consideration the inter-temporal dimension), the anticipated growth rate of the energy prices (to take the expectations into account), the energy use cost to take into account the inter-temporal energy cost for a firm to implement a technique using capital and labor, etc. would no doubt

7. This is the case of Benin and some of Nigeria's neighbours where the informal market for oil products operates in line with market laws and where a large proportion of consumers get their supply.

improve the quality of results. However, this work leads to some major policy recommendations.

4.2. Economic Policy Implications

The results suggest that structural effects have a positive long-term impact on energy demand at regional level. Even though the structure of the economies shows a very slow change in agriculture and industry in the total value added at regional level, that is about 36% and 18% respectively in recent years, it is important to note that the choice of a growth-based on the recovery of the agricultural sector with a strong interrelation with agro-industry indicates strong pressure on energy demand in the future. It means that these options must be accompanied by rapid development of new capacities at regional level. The regional option chosen by the countries should be encouraged because not only does it generate economies of scale, but more so because the available potential is unequally distributed among the countries of the sub-region. This potential is currently under utilized because of low operating capacity and inadequate technological choices that are very costly in terms of loss, particularly in the electricity sector. Moreover, regionalization will facilitate obtaining the enormous financial requirements needed to put in place the capacity to tap the potential. The approaches being promoted by the common UEMOA energy policy, and also by the ECOWAS energy protocol for greater private sector involvement must be encouraged: they are all based on measures that promote public-private partnership for producing and supplying electricity, and even bio-fuel. An example of this regional approach can be seen in the West African GAZODUC project which represents an investment designed for the use of Nigeria's gas to supply Electricity Stations in neighboring countries. A variant of the regional approach, which has been experimented for several decades, consists in making electricity interconnections. Therefore, two areas may be distinguished: that known as A[8] which groups Benin, Burkina Faso, Cote d'Ivoire, Ghana, Niger, Nigeria and Togo, and Zone B made up of the other member States. One of the strategic objectives of EEEOA is the development of regional interconnection infrastructure with high private sector involvement. It is desirable that as this strategy is implemented, it should focus on establishing regional production infrastructure rather than shared national infrastructure. This means increased responsibility of various States and a lower risk of seeing nationals continue to question an approach which, according to them, is not synonymous with autonomy since it will secure supply based on management rules laid down by a Regional Authority.

The relation between per capita income and energy demand is an important energy policy challenge. Indeed, the energy-poverty issue emerges very

8. Areas created by ECOWAS according to inter-connection level in the context of the EEEOA project. Zone A is at a more advanced level thank Zone B

clearly in the Community's energy situation. The traditional sources (fuel wood, charcoal, agricultural residues, animal waste) provide on average up to 80% of energy. For lack of possibilities, these traditional sources are over-used (consumption exceeds local production). Equipment items in the poorest countries are very energy-consuming. For example, the consumption of cars and trucks has dropped by 30% in recent years thanks to the progress made in the design of modern engines, although there are very few new vehicles in the vehicle fleet of poor countries [9]. Similarly, the energy output of their industrial installations is on average three times lower than that of industrialized countries. Companies should have their own generators to offset the deficiencies of production centers and shortcomings of the supply systems. This would represent one-quarter of the investment of small enterprises in these countries. We see that apart from the issues of capacity, the problems of energy type also arise and must be promoted in the sub-region. Current practices have a very negative effect on the environment and the findings suggest that an improvement in the per capita income level contributes to lowering the pressure on demand. This will mean offering credible substitution alternatives to households because only a few are currently connected to electricity supply systems and fewer still in a considerable number of countries are concerned by the use of butane or propane gas for cooking. Better incomes, not followed by available supply of electricity, cooking gas and any other form of energy that could decrease the pressure are still inadequate. Measures aimed at decreasing the share of the biomass in energy consumption must be encouraged as the use of this form energy is a serious threat to the environment. Subsidies for promoting cooking gas, given its weight on the State budget must not be abolished, as the resulting increase in the price of gas, together with a possible drop in the per capita income, could contribute to less efficient energy use. Some countries must review their gas bottle retake policies so that people will have bottles for their gas supply and thus give the substitution effect all the chances for full success. Indeed, until now, the costs of entry into the gas supply system are high in most countries since incomes are low. The issue of adopting this form of energy for cooking may arise, but the contribution of NGOs in their role of communication for change in behavior may help to achieve that objective.

The relationship between energy demand and per capita income indicates therefore that any measure that will help improve per capita income is welcome for efficient use of the country's energies. From the macro-economic standpoint, economic policy measures for growth and for an increase in per capita income will have to be implemented. On the macro-economic front, this result reveals the link between energy demand and poverty: poverty reduction means more efficient use of energy and, consequently, environmental protection. Poverty prevents households from acquiring low energy consumption equipment, and increasingly from access to modern power

9. *Source:* http://www.science-decision.net, consulted on 30 August 2008

supply systems the initial costs of which are exorbitant given their income level. The "energy ladder" shows that as and when households climb the ladder, increasing their modern energy consumption as they ascend, their economic well-being improves and so does their income potential. The poorest households occupying the lowest level of the energy ladder usually have little or no access to modern energy services, and must use the traditional fuel, such as fuel wood, charcoal, etc. Sub-regional authorities should ensure that modern energies are available and affordable to low income households.

The strong link between these two concepts makes it very problematic for authorities to take action. For example, an administrative decision taken by the States to maintain energy prices below the cost price so as to facilitate access of the poorer households to energy may in reality reduce its availability, because service providers will think that it is not profitable to extend the area served to poorer neighborhoods. The State should at the same time ensure that the billing method adopted brings about not only a good turnover on the invested capital, but ensures that energy is available in the long term and bills sent to the users of the various systems (gas and electricity) are reasonable. The increase in consumption that the measures will generate and the already visible external factors mean that the authorities must play the role of "major risk" manager. This question may, taking into account the continued surge of oil prices, rekindle interest in nuclear energy. It may be high time that the sub-region's uranium resources are in part used to supply a regional civil nuclear station that would offer a choice alternative to hydroelectricity, very often vulnerable to natural disasters, even though the untapped potential is enormous.

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Annex

Hausman Test

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V—b-V—B))
	fixed	.	Difference	S.E.
lagvalu	.622871	.70947	-.086599	.0633308
lindvalu	.179957	.3130328	-.1330759	.0540766
lprix	.0217103	.0114018	.0103085	.0040081
lpitet	-.2002511	-.3406895	.1404385	.0744212

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 9.80
Prob>chi2 = 0.0439
(V_b-V_B is not positive definite)

Results of Test xttest2 or Test LM of Breusch and Pagan (1980)

Correlation matrix of residuals:

	__e1	__e2	__e3	__e4	__e5	__e6
__e1	1.0000					
__e2	0.4894	1.0000				
__e3	0.1662	0.7624	1.0000			
__e4	-0.1255	-0.3072	-0.1854	1.0000		
__e5	0.7250	0.6431	0.3812	-0.5466	1.0000	
__e6	0.2820	0.8608	0.7189	-0.3044	0.5690	1.0000

Breusch-Pagan LM test of independence: chi2 (15) = 128.033, Pr = 0.0000
Based on 31 complete observations over panel units