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The impact of predicted demand on energy production

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Abstract. Energy is crucial for human life, a secure and accessible supply of power is essential for the sustainability of societies. Economic development and demographic progression increase energy demand, prompting countries to conduct research and studies on energy demand and production. Although, increasing in energy demand in the future requires a correct determination of the amount of energy supplied. Our article studies the impact of demand on energy production to find the relationship between the two latter and managing properly the production between the different energy sources. Historical data of demand and energy production since 2000 are used. The data are processed by the regression model to study the impact of demand on production. The obtained results indicate that demand has a positive and significant impact on production (high impact). Production is also increasing but at a slower pace. In this work, Morocco is considered as a case study.

1. Introduction

The energy demand should increase considerably in the coming years because of the increase of the population and the economic development (EIA, on 2007). Gradually as economics spend some concept of subsistence to that of industrial production or services, the lifestyles of numerous individuals will know of deep changes. The main increases of energy demand will be the fact of the developing countries where the percentage of the world consumption of energy should cross 46 to 58 percent between 2004 and 2030 (EIA, on 2007). It is planned that the energy consumption in developing countries will increase at an annual average rate of 3 percent between 2004 and 2020. In industrialized countries, where the state economies are mature and the population growth should be relatively weak, the energy demand will progress more slowly at the 0, 9 percent rate a year, although the starting point is much higher. The increase of the world demand for 2030 will be attributable in the electricity production and the fifth at the needs for transport, in particular in the form of petroleum-based fuels (EIA on 2007). The electrical energy can be an important element of any strategy wished to improve the environment provided that the consequences at the level of his production are mastered.

2. Literature review

There are various types of conventional and no conventional sources of energy used for electrical power production. The system of solar and wind energy is one of the most important sources of energy. The exploitation of solar and wind energy became more and more necessary because of the nature modular and favorable to the environment [1]. The modeling of energy demand can follow either the approach with a variation of time or the approach with fixed coefficients. Nevertheless, he can be necessary to estimate the underlying statistical behavior of the parameters of energy demand before any significant inference. Z. Mohamed et al. used the model of multiple linear regression based on the gross domestic product, the price of electricity and the population to forecast consumption in New Zealand [2]. M. Tunç et al. studied and compared the world production of electric energy from different power sources with electricity generation in Turkey [3]. S. Jebaraja et al. presented various types of models used in the literature such as energy planning models, model supply, demand of energy, prediction models, and renewable energy patterns, emission reduction and optimization models [4]. Y. Lee et al. proposed a model that combines Grey residual modification with genetic programming. They concluded that the model is offering a predictive accuracy than other models [5]. On the other hand, a method of energy consumption based on gross domestic product and population by a model of linear regression exhibited by G. Aydin. 2014. The author concludes that several approaches validate the model, and it can be used to predict the energy consumption of Turkey [6]. C. Adjamagbo et al. suggested four mathematical models for modeling the energy demand in Togo [7]. D. Neto Studied diesel demands in Switzerland by an iterative methodology for the long term. The model based on Chebyshev polynomials in two steps for short-term dynamics [8]. Huneke et al. [9] used the linear programming to obtain an optimal configuration for a combination of generator with wind power - solar energy - battery- diesel for two real powers except for network systems in India and Colombia. The results of optimization for both studies show the possible combination of cells- PV-and diesel generator. In this paper the main contributions are: (i) studying the impact of predicted demand on production; (ii) using the linear regression method to find the best results; (iii) the presentation of preliminary simulation results showing that demand has a positive and significant impact on production. This work is the result of the two previous studies [12], [13].

3. Interest of study

As aforementioned, this study is based in Morocco, which has seen an energetic evolution. The main interests of studying the impact of predicted demand on energy production is that to be able of managing and coordinating DGs, storages, and loads in a more decentralized way reducing the need for the centralized coordination and management. Hence, the optimization of production cost is extremely important in order to cost-efficiently manage its energy resources [14]. The population and economic trends followed by a fast increase of the energy consumption (i.e., increase in the electricity intensity) impellent the countries of the world to lead studies on intersection points between the demand and production. This pattern put them in an unusually favorable situation to implement diverse formulate of reduction of the impact, reducing so at least the uncertainties as for their costs and their advantages. Our paper leads a study to determine the impact of the demand on the energy production to improve the energy efficiency. In addition to achieve the following objectives:

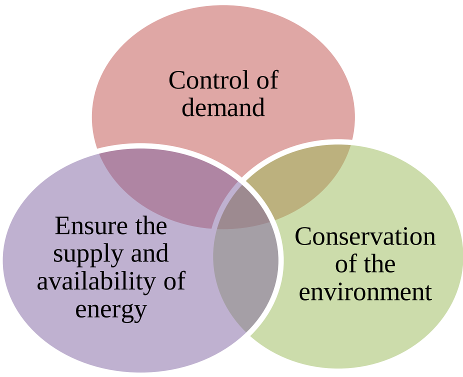

Figure 1. The interest of the study.

4. Methodology

A flow chart for the study is presented (see Fig. 2). This study collects monthly data on Morocco's energy demand and production between 2000 – 2015. Modeling by linear regression is used to examine the impact of demand on energy production in per month in future. In this model, the production is defined as the dependent variable and the demand as an independent variable. Adjustment measures are calculated through R-square and R-square adjusted, and the equation of production determined. The SPSS 20 statistical software which offers a choice of linear regression is used for the analysis. According to the previous studies of demand in [12] and energy production in [13], this represents a first attempt to specifically study the impact of predicted demand on energy production in Morocco. The first target of the present paper is the collecting data, analysis and selecting the methodology. The second target is modeling of the dependent variable as a function of independent variables. The third target is to provide an accurate model for linking demand to production using historical data for demand and energy production.

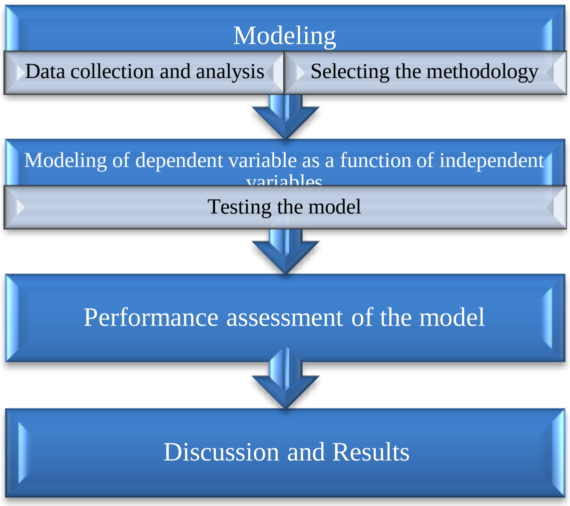

Figure 2. The stages of the study.

The figures below show the evolution of energy demand and production monthly during the 15 years.

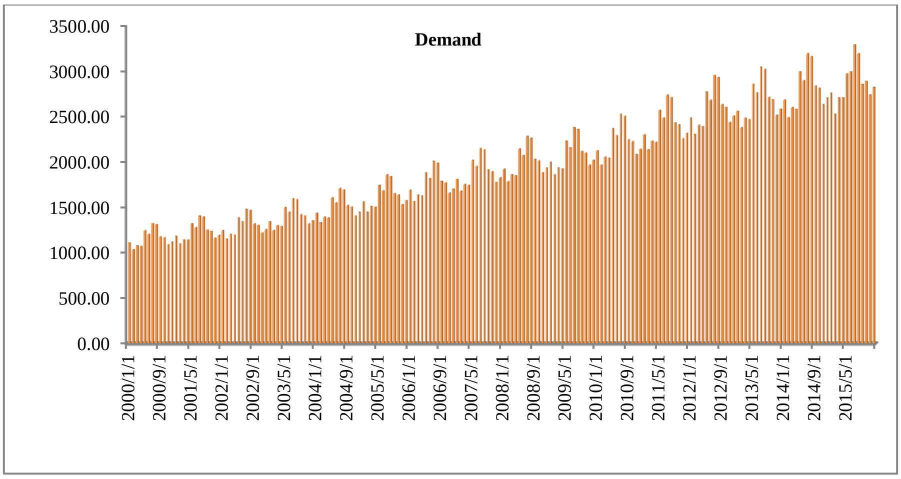

Figure 3. Evolution of energy demand (2000-2015).

From Fig.3 demand decreases seasonally with the temperature when it is cold, whereas higher temperatures increase the electricity consumption due to running cooling devices during the warm periods.
The forecast of energy demand had already studied by the ARIMA model in [12] to determine the needs of consumers in the future years. Therefore, the prediction equation can be formulated as follows:

$$Demand = 3.830e^{-6T} - 49415.523 \pm R \qquad (1)$$

With:

D: Demand for energy consumption
T: The time of development in months

R: Includes all elements affecting demand and which are not considered by the model, in addition to the errors in calculating the coefficients.
In this model, the demand is defined as dependent variable, and the time as an independent variable. The model is validated by various statistical approaches such as the determination coefficient, R-square, R-square stationary.
It is concluded that the model can be successfully used as a prediction tool for Moroccan's energy demand [12].

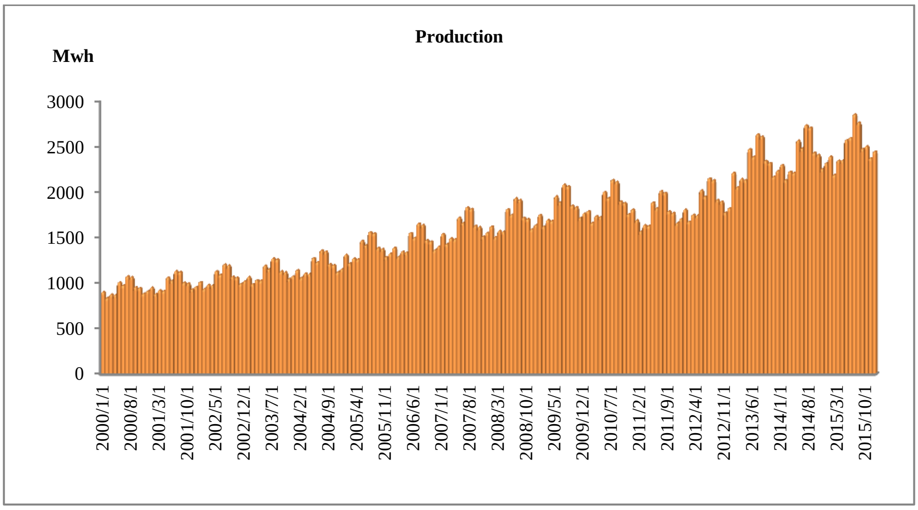

Figure 4. Evolution of energy production (2000-2015).

The forecast of energy production had already studied in [13]. In this case two models are used to predict energy production: polynomial curve fitting and linear regression. The obtained result show that the polynomial curve fitting can be used to predict energy production. In 2012, the power production increased through the construction of new farm of electricity production. Morocco has a considerable potential for electricity generation from the solar energy.
In line with these challenges, this paper focuses on the Moroccan energy and on the potential impact of demand on production. Specifically, this paper explores the effect of demand variable on energy production by analyzing the direct impact of consumption on the electricity production. Hence, demand is a major determinant of electricity production. Moreover, this question is currently of crucial concern given the observed of integrating renewables.
A limitation of our work is that we do not distinguish between residential, commercial and industrial demand for electricity. We quantify the impact of demand variation on energy production only at a national level.

5. Modeling

In this study, different methods were used before choosing the linear regression that gave us satisfactory results.

5.1. Linear Regression

The Regression models are used to study the influence of economic variables on the annual electricity consumption in N. Cyprus is examined [15]. In [16] have examined the nonlinear relationship between energy demand and temperature in the European Union. In [17] examined the dynamic relationship between energy consumption, weather, and price and consumer income. In [18] analyze the linear and nonlinear effect of energy demand on economic growth for Taiwan. The obtained result shows that a threshold regression provides a better empirical model than the standard linear model. The aim of this study is to analyze the difference between the energy demand and production using linear regression for having the anticipation in the future. The integration of renewable energies (e.g., solar and wind) requires a study on the needs of consumers for defining the energy to be produced. Currently,

conventional energy will be unable to cope with future energy requirements. Conventional production (e.g., Fossil fuel and nuclear) are closely linked to environmental deterioration. It is therefore clear that if the increasing energy needs are to be met with preserving the environment.
Renewable energy sources that use natural resources have the potential to provide energy services with almost nil emissions of both air pollutants and greenhouse gases. Renewable energy sources (i.e., solar energy, wind power, biomass and geothermal) are independent, inexhaustible and widely available. These resources can meet the present and future energy demands of the world as presented (see Fig.5).

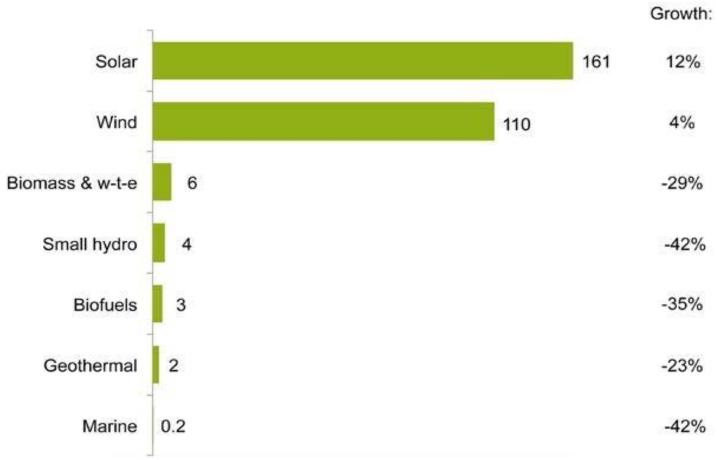

Figure 5. Global investment in renewable energy by technology, developed and developing countries, 2015 [18].

The evolution of renewable energy sources can enhance diversity in energy supply markets, contribute to securing long-term sustainable energy supplies, help reduce environmental impacts and provide commercially attractive options to meet specific energy service needs.
The simple linear regression model is represented by the following equations:

$$y_i = a * x_i + b + \varepsilon_i \tag{2}$$

Where y_i is the value of the dependent variable in observation i, x is independent variable in observation i, a and b are fixed quantities. ε is error term in observation i.

5.2. Test the equality of averages

The probability to know the average of a sample pulled at random can be calculated with the test T-Student. To test this probability for the variables which have in our database. The hypothesis of departure appears as follows:
H0: the average of the studied variables is likely if we pull a sample at random.
H1: the average of the studied variables is not likely if we pull a sample at random.
The results of the test appear as follows:

Table 1. Test on Single Sample

	Test value = 0					
					Confidence interval of difference to 95 %	
Model	t	ddl	Sig. (bilateral)	Average Difference	Inferior	Superior
Demand	46,829	191	0,000	1966,128894187558	1883,3136768	2048,94411147
Production	44,862	191	0,000	1626,418640799437	1554,9095188	1697,92776278

The results of the test T of Student shows that average of the samples is not likely for all the variables of study (test T is very significant for all the variables p - been worth = 0.000) and thus the hypothesis H0 is rejected and H1 is accepted. We conclude that samples possess an extremely improbable average for all the variables of the study.

5.3. Test the normality of variables

To test the normality of variables, the statistics of Kolmogorov-Smirnov for a sample are appealed. The hypothesis of search announce as follows:
H0: the studied variables follow a normal distribution.
H1: the studied variables do not follow a normal distribution.
The results of the test appear as follows:

Table 2. Kolmogorov-Smirnov Test for a Sample

		Demand	Production
N		192	192
Normal settings a,b	Average	1966,128894187558200	1626,418640799437500
	standard deviation	581,771064715872900	502,346542018328760
Most extreme differences	Absolute	0,077	0,081
	Positive	0,077	0,081
	Negative	-0,060	-0,062
Test statistics		0,077	0,081
Sig. asymptotic (bilateral)		0,008c	0,004c

a. The distribution of the test is Normal.
b. Calculated from the data.
c. Correction of Lilliefors.

The results of the statistics of K- show themselves that can reject the hypothesis according to which variables follow a distribution according to a law normal (Statistics of the test are very significant for the set of variables p- been worth = 0.000) and the hypothesis which stipulates that the variables of study do not follow a normal distribution can be accepted. (i.e., Rejected H0 and H1 Accepted).

5.4. Information on the regression model

Modeling by Regression is used to analyze the variations of the power production according to the demand. In this model, the variable production is defined as dependent variable, and demand as being an independent variable. Also, the measure of adjustment is calculated through R-square. The study of the impact of the variable "Demand" on the "Production" allowed verifying certain tests to validate the results of regression.
The results of the Test of Homoscedasticity, Test of independence of the terms of the error, the normality of the distribution of the terms of the error and finally the Test of collinearity are satisfactory, and thus we can accept the results of the models.

Table 3. Model Summary

Model	R	R-square	R-square adjusted	Standard Error of Estimate
1	0,979 a	0,959	0,959	101,840413665507740

a. Predicting: (Constant), Demand. b. Dependent variable: Production.

Using the analysis of the table above, gave a good model since “R2 = 0.959”, which explains that the explanatory variable contributes almost “95.9%” to the variability of the variable to be explained is production. Thus, the analysis of the results of the F-Fisher test and more particularly the variation of F in order to test whether the most recent contribution presents a significant improvement in the prediction capacity in the regression equation. Important value of the variation of F-Fisher is noticed as it is very significant. This means that the regression equation is good and the explanatory variable contributes very significantly to the scores of the variable production as it is displayed in the table below.

Table 4. Anova[a]

Model		Sum of squares	ddl	Average square	F	Sig.
1	Regression	46228661,948	1	46228661,948	4457,291	0,000b
	Residue	1970579,273	190	10371,470		
	Total	48199241,221	191			

a. Dependent variable : Production
b. Predicting : (Constant), Demand.

The aim of using ANOVA method is for analyzing the influence of the different parameters of linear regression.
The table below shows that there is a statistically impact significant (0.846: p-value = 0.000) of the demand on production. Therefore the demand is the most important determinant for the explanation of production.

Table 5. Model Statistic

Model	Non-standardized coefficients		Standardized coefficients	t	Sig.
	B	Standard Error	Bêta		
(Constant)	-36,224	25,966		-1,395	0,165
Demand	0,846	0,013	0,979	66,763	0,000

The equation linking demand to production can be presented as follows:

$$Production = C + \alpha * Demand + \mu \quad (3)$$

With:
C: Constant which represents indestructible production
α: Represents the estimated parameter of the relationship between demand and production
µ: Standard Error

The final equation of the regression is:

$$Production = -36.224 + 0.846*Demand \pm 101.84 \quad (4)$$

Demand has a positive and significant impact on production (high impact). When demand increases, the production also increases, but at a slower pace. (i.e., estimated parameter is between 0 and 1).The constant gives a negative sign. The following charts are the graphs that check the hypothesis of Homoscedasticity, the independence of the terms of the error and the normality of the distribution of the terms of the error.

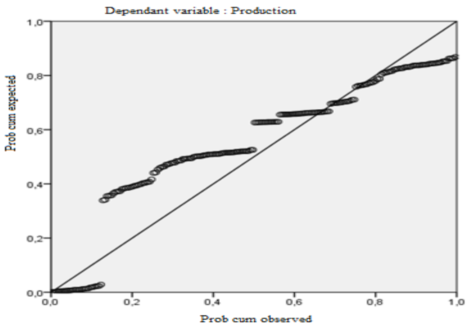

Figure 6. Standardized regression plot

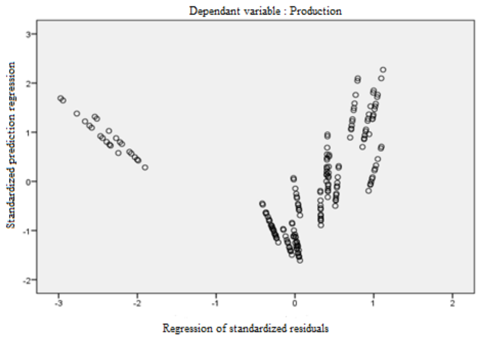

Figure 7. Cloud of point.

In Fig 6 the diagram shows that the distribution of the residues follows the normal distribution, which means that we have a normal distribution of the terms of the error. (i,e. quasi-linear form). In Fig 7 the published scatter of standardized residues in relation to the standardized predicted values does not reveal any particular model, which confirms the assumption of the constant value of the variance of the error term (Homoscedasticity) error.

6. Conclusion

Regression modeling is used to analyze changes in energy production as a function of demand. In this model, the production as a dependent variable and the demand as an independent variable are defined. The fitting measures through R-square and R-square adjusted are calculated. Energy demand is studied with ARIMA model which has a significant result. In this paper, the impact of predicted demand on energy production in Morocco is examined using a linear regression method applied to the last 15 years. Moreover, regression has shown the electricity demand in Morocco, has a positive and significant impact on production. The sensitivity of the demand is higher in the warm period.

In sum, this paper shows that the demand is a major determinant of electricity production in Morocco and that the sensitivity of electricity consumption to temperature has increased in the recent period.

This work allows to mastering the energy transition, satisfies the energy demand and reduction of the energy bill. As well as to assure the management of the energy transition by considering the necessity of protecting the balance of the sector.

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