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Energy needs for Morocco 2030, as obtained from GDP-energy and GDP-energy intensity correlations

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HIGHLIGHTS

- We present several mathematical models for country-level energy intensity.
- We introduce the concept of the "partial energy intensity" for each energy segment.
- We use mathematical models that historically work best for each one.
- We extrapolate the models into the future to get their forecasts.
- We use these lasts to calculate forecasts of needs in terms of final energy.

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ABSTRACT

We present forecasts of the energy consumption of Morocco towards 2030. Two models have been developed and their results compared: one based on the energy intensity (IE) and another one on a link with the country urbanization rate (URB). The IE model allowed to segment energy consumption in four posts while the URB model only in two posts. For the sensitivity analysis to economic growth, three future GDP evolution scenarios are proposed. The retrospective correlations of both models are excellent but their future extrapolations finish in slightly different results. Through their correlation to electricity consumption, peak power forecasts are also presented. A forecast of the country energy intensity is commented. As the average yearly increase of electricity should still be between 4.9% and 7.1% during 2020–2030, the electric equipment program continuation after 2020 must soon be clarified and avoid the former implementation delays. As the white combustibles needs should yearly increase between 6.3% and 7.8% in 2020–2030, electrical equipment programs should also make provisions for the case of deployment of electric cars. Butane subsidies widen the gap with other fuels and must be removed very soon possible to reduce the growth of its consumption and energy intensity.

1. Introduction

Economical sustainability is a critical issue for countries having a very high energy dependence index like Morocco (> 95% in 1999–2008). More than for others, for a country so exposed to the increase and volatility of the international primary energy prices, the energy intensity must absolutely stay at the lowest level possible.

1.1. General considerations

The notion of "causality", related to variables having "caused" a given phenomenon, is, from our point of view, often wrongly confused with the notion of "correlation" which is a statistically established mathematical link between an observed phenomenon and one or more variables. The existence of a correlation does not necessarily mean that the variables are the cause of the observed phenomenon, but that it adopts a mathematical behavior related to the changes of the aforementioned variables. To analyze and understand the behavior of the energy consumption of a given country, macroeconomic aggregates offer a wide choice of variables chief of which is, in general, the gross domestic product, as shown in Fig. 1. Its data are taken from the IMF, International Monetary Fund (2010) and the US Department of Energy (2006).

Increasing energy costs and availability of more efficient equipments for energy conversion (power plants, vehicles, lighting, household electrical appliances, etc.) both should moderate the correlation of energy consumption and GDP. However, this correlation remains strong in DCs because the process of access to energy is incomplete (for their citizens and their production tools).

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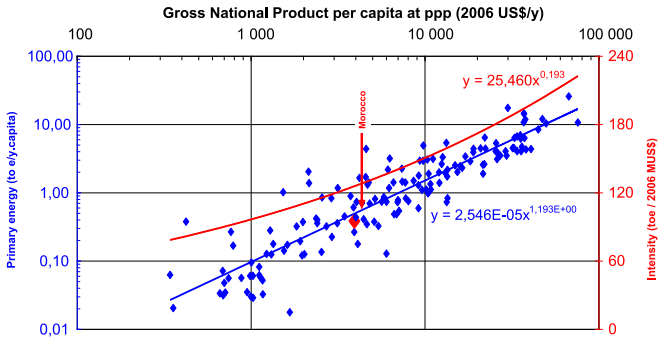

Fig. 1. 2006 Energy and GDP adjusted for purchase power for 156 countries on left scale in blue and its related average energy intensity on right scale in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

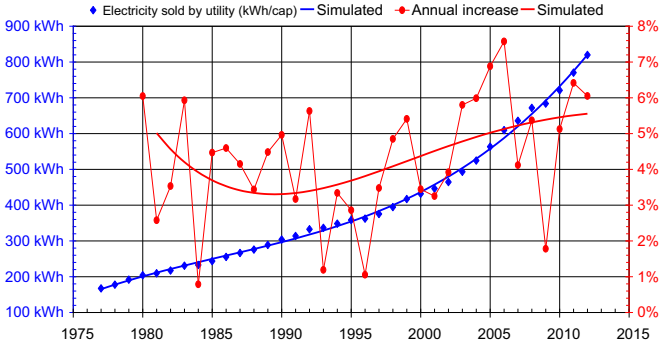

Fig. 2. Evolution of electricity per capita called by the grid in Morocco (on left scale in blue) and its related yearly increase (on right scale in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 2 shows how, the 1995–2002 period was a turning point in Morocco between two electricity consumption regimes: before 1995, it was increasing by around 11 kWh per year and per capita, while after 2002, it went to a faster regime, increasing around 39 kWh per year and per capita, essentially (but not only) because of the Global Rural Program of Electrification (PERG) grid extension. As this work is devoted to a segmented forecast of the Moroccan energy consumption, the presence of such turning points in the Moroccan past imposes to use historically well-established correlations capable to transcend cyclical phenomena like the one shown in Fig. 2. Its data are taken from the Moroccan utility ONEE, Office National de l'Électricité (1996–2012a, 1996–2012b).

If a statistical quality index (like the correlation coefficient) of a given retrospective correlation defines the precision of the model, the duration of its past validity is a security for the model extension towards the future. This is why this work will use the oldest available reliable data from Moroccan sources (from 1980 when available, 1985 otherwise).

1.2. Quick literature overview and the positioning of this paper

1.2.1. On energy-income correlations

In a study of over more than hundred countries, Chontanawat et al. (2008) found that the causal relationship between energy consumption and economic growth is more pronounced in developed than in developing countries. But we hope that things have changed in the last decade otherwise their energy efficiency policy efforts would be simply useless to reduce CO_2 emissions while continuing growing.

As Bruns and Gross (2012) have counted no less than 534 causality tests for 77 countries in 44 studies on the energy consumption-economic growth nexus, it can be stated that the topic has been intensively studied over the 35 last years, since Kraft and Kraft (1978) article, which is recognized as seminal by most authors. In addition, basing their remarks on 24 representative publications on the topic (dated between 1978 and 2012), Coers and Sanders (2013) have shown that a consensus on modeling has still not emerged and that previous work to 2013 can broadly be divided at least into:

1. Five categories of methodologies: simple causality tests, bivariate and multivariate Vector Error Correction (VEC) model in addition to bivariate and multivariate panel VEC model.
2. Four categories of results: no causation, causation from energy to GDP, causation from GDP to energy in addition to bidirectional causation.

1.2.2. On energy intensity

Analyzing several works, Adom (2015) highlighted two contrasting arguments concerning the effect of income increase on energy intensity:

1. When dedicated to *purchases* of energy-using appliances, income rises may result in energy intensity increases, except if the purchase is used for energy efficient ones, where the energy intensity may decrease. According to this argument, an income increase causes a scale effect.
2. When dedicated for *replacements* of old equipment with energy-efficient ones, income rises may result in an energy intensity fall (income rise higher than energy use increase).

Developing countries have high economic growth rates and Bernardini and Galli (1993) outlined three reasons why higher income may slow down energy intensity:

1. First, rising income changes the final demand structure, passing through different industrialization phases.
2. Second, rising incomes or higher GDP leads to technological progress that improves energy efficiency.
3. Third, technological progress also leads to the usage of substitute equipment that is less energy intensive.

Overtime, the rebound effect argues that efficiency gains may lead to increase energy consumption.

Mixed income effects create the possibility of a nonlinear behavior, which opens another strand of the literature which has focused on the nonlinear relationship between energy intensity and income.

1.2.3. On energy-GDP studies including Morocco

Energy-income nexus of Morocco has been studied essentially for comparison purposes with:

1. Senegal and Ghana by Adom et al. (2012) who found that carbon dioxide emission acts as a limiting factor to economic growth in Morocco and Ghana.
2. South Africa, by Mans (2014) who compared the links to local green economies,
3. Other 4 North African countries by Marktannera and Salman (2011) who argued that the identification of any energy alternative as superior is hardly convincing unless certain standards of inclusive governance are met; they also highlighted the political–economic differences of energy importers like Morocco,
4. Other 13 members of the Organization of Islamic Conference by Gabbasa et al. (2013) who focused on their energy supply status