THE IMPACT OF WORLD POPULATION GROWTH ON GLOBAL ENERGY CONSUMPTION: A PROBABILISTIC ANALYSIS

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Overview

Apart from the price of energy, there are two influencing factors that control global primary energy consumption, namely the total number of people in the world and the average per capita energy consumption of each individual. While per capita energy consumption is falling in a large part of the OECD countries, it is rising in other countries, e.g., in the Middle East. A global energy demand forecast to 2050 is presented, based on historical growth in per capita energy consumption over the period 1965-2021 and on United Nations population projections.

Methods

Average per capita energy consumption is forecast using modern time series models, the Autoregressive Integrated Moving Average (ARIMA) models. Finally, the results of the time series forecasts are combined with stochastic UN world population projections to obtain forecasts and prediction intervals of total energy consumption from 2022 to 2050. We use autocorrelation function (ACF) and the partial autocorrelation function (PACF) in tandem to identify the stochastic process of per capita energy consumption between 1965 and 2021. ACFs and PACFs together with the mean of the first differences indicate an ARIMA(0,1,0) model with drift. More complicated ARIMA models were also considered, specified, estimated and used for forecasting. An alternative would have been an ARIMA(0,1,1) model with drift. However, we were always aware of the principle of parsimony which means that in a set of predictive models, the simplest possible models should be chosen. Assuming a normal distribution, the standard deviations or variances of total primary energy demand are determined from the limits of the given prediction intervals of per capita consumption and world population.

Results

The forecasts of the global per capita energy consumption are shown in Table 1. In 2050, the point forecast for the world per capita consumption is 90.6 GJ, which corresponds to an annual (steady) growth rate of 0.62 percent between 2050 and 2022. We describe the uncertainty by the 95% prediction interval. The lower bound is 77.4 GJ and the upper bound is 103.8 GJ in 2050. The mean forecast values from 2022 to 2050 as well as the resulting limits of the 95% forecast intervals of world total primary energy consumption are shown in Figure 1. In 2050, the median forecast is 879.3 EJ. The 95% forecast interval ranges from 748.2 EJ to 1010.4 EJ. The prediction intervals clearly show the growing uncertainty with increasing forecast horizon. In addition, the influence of population and per capita consumption on the forecast is analyzed. The median forecast of total energy consumption leads to an average annual growth of 1.32 percent, whereby the influence of the world population, which grows 0.70 percent annually, is somewhat higher than the per capita energy consumption, which increases 0.62 percent annually. Conditional forecasts show that the uncertainty in forecasting total primary energy consumption is mainly due to the uncertainty in forecasting per capita energy consumption (see prediction intervals in Table 1), whose prediction intervals are much larger than those of the world population.

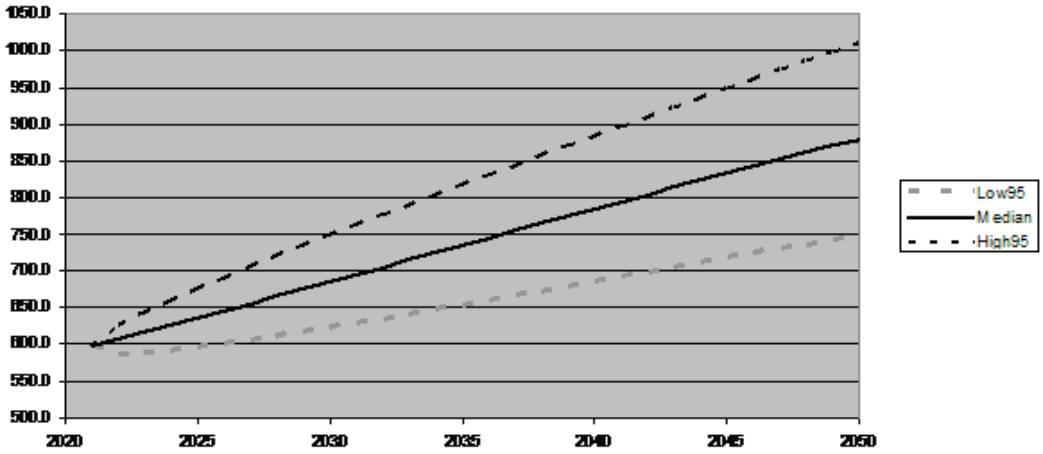

Fig. 1. Forecast of the world primary energy consumption with 95% prediction intervals (exajoules)

Table 1. Forecasts of primary per capita energy consumption (gigajoules)

Year	Forecast	Lo 80	Hi 80	Lo 95	Hi 95
2025	77.7	74.5	80.9	72.8	82.6
2030	80.2	75.4	85.1	72.9	87.6
2035	82.8	76.8	88.8	73.7	92.0
2040	85.4	78.4	92.4	74.7	96.1
2045	88.0	80.1	95.8	76.0	100.0
2050	90.6	81.9	99.2	77.4	103.8

Conclusions

The prediction of global primary energy consumption is based on a combination of the prediction of per capita energy consumption and the prediction of world population. The results clearly show that total primary energy consumption depends on both future per capita energy consumption and future population growth, with both variables having about the same influence. In contrast, the uncertainty in the global energy forecast is largely driven by the uncertainty in the per capita primary energy consumption forecast, although the future of world population growth appears more uncertain today than it did a decade ago due to stagnant fertility decline in some African countries. The proposed model uses only past values for forecasting. Causal factors affecting energy demand are not considered. Time series methods for forecasting the future are suitable as long as demographic, social, political, and economic change is slow, continuous, and without breaks or sudden changes in direction, and the past, present, and future differ only slightly.