**Supplementary material: Data and code description**

*1. Data*

* 1. Energy data

OWD data (TWh)

where PRE is Primary Renewable Energy, RE, Renewable Energy; PE, Primary Energy (total); , Primary Renewable Energy corrected, and, , Primary Energy corrected (total). Super index ‘o’, meaning OWD, is omitted for clarity.

Linking Malanima’s () and corrected OWD’s ():

Mtoe = 11.63 TWh

where is the final Primary Energy including renewable energy. This is done for all individual countries. The aggregate is obtained summing all countries.

1.2 GDP

where , is the GDP from the World Bank, and is the Madison’s GDP. Done for all individual countries, and the aggregate summing them all. GDP is the final series.

1.3 Population

(4)

where is population data from the United Nations population department, and, , is Madison’s population data. POP is the final world population series. For all individual countries. The aggregate is obtained summing all countries.

*2. Estimation procedures*

2.1. Interpolation

The methodology follows standard implementation in official statistical institutes. It estimates the interpolated series by minimizing its discrepancy with the available indicator, while simultaneously constraining it to be equal to the observable values at the available dates – discrepancy measured as overall quadratic deviations. More details in [59 ]:

Sax, C, Steiner, P. Temporal Disaggregation of Time Series. The R Journal. 2013;5(2):80-8. https://doi.org/10.32614/RJ-2013-028

2.2. Trends

A level 5 wavelet decomposition implemented with the R function waveslim::modwt using a Discrete Wavelet transform with the orthonormal Daubechies wavelet filter of length L=8, la8. The series trend is reconstructed making the wavelet coefficients d1 to d4 equal to zero with the function waveslim::imodwt. More details in [63].

Gencay R, Selcuk F, Whitcher B. An Introduction to Wavelets and Other Filtering Methods in Finance and Economics. Academic Press; 2001. <https://doi.org/10.1016/B978-0-12-279670-8.X5000-9>

2.3 Variable selection

Variable selection is conducted with the methodology of [Zhu](https://www.pnas.org/doi/full/10.1073/pnas.2014241117#con1) J,  [Wen](https://www.pnas.org/doi/full/10.1073/pnas.2014241117#con2) C, X. A, (2020), and implemented in the R abess package and the function abess::abess.default. The procedure selects the most likely variables among a given set, that explain the behaviour of a response variable. In the present case, the explanatory variables are: GDP, Population, Temperature, energy prices, all in levels and first differences, plus two lags of all variables, making a total of twenty four variables. Thus, adding the constant, 25 variables are considered to explain 102 observations. The usual procedure of trial-and-error considering variables, or sets of them, one at a time, is time consuming and uncertain, since there is no clearly defined pathway to implement it.

The ‘abess’ procedure identifies the main variables quickly, and a further test of significance for the excluded variables confirms that there are no statistically significant omitted variables. More details in [65]:

([Zhu](https://www.pnas.org/doi/full/10.1073/pnas.2014241117#con1) J,  [Wen](https://www.pnas.org/doi/full/10.1073/pnas.2014241117#con2) C, X. A polynomial algorithm for best-subset selection problem. PNAS. December 16, 2020;117(52):33117-23. <https://doi.org/10.1073/pnas.2014241117>)

2.4. Support Vector Machine

Following the methodology of Chang and Lin (2022), implemented in the R package kernlab and the function kernlab::ksvm.

Kernel = (Laplace, Rbf) (5)

Cross Validation (CV) is implemented, with data split into 5 subsets; the forecast error of the CV estimation is the selection criterion, i.e., the parameter combination that yields the minimum forecasting error (cross). Note that the selection criterion is not the minimum fitting error, since that would yield an overfitted model with suboptimal forecasting behaviour. More details in [67]:

(Chang Chih-Chung, Lin Chih-Jen. LIBSVM: a library for Support Vector Machines. Dept. of Computer Science, National Taiwan University, Taipei, Taiwan (2022)

https://www.csie.ntu.edu.tw/~cjlin/libsvm/)

3. *Data sources (all public)*

Energy prices

- WB World Bank. Commodity Markets. “Pink Sheet” Data. Washington DC, US.

<https://www.worldbank.org/en/research/commodity-markets>.

GDP

- World Bank. World Development Indicators. Washington DC, US.

<https://databank.worldbank.org/source/world-development-indicators>.

GDP and population

- Maddison A. World-Gdp-Over-The-last-Two-Millennia, (1000–2008). Available online: <https://www.rug.nl/ggdc/historicaldevelopment/maddison/>

- Maddison Project Database (MPD) 2020

<https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2020?lang=en>

Population

- United Nations. 2022 Revisions of World Population Prospects. Department of Economic and Social -affairs. Population Division. NY, US. <https://population.un.org/wpp/>

Energy (primary) and electricity

- OW Our World in Data. Available online: https://ourworldindata.org/

- Malanima, P. WEC World Energy Consumption. A Database 1820-2020

<https://histecon.fas.harvard.edu/energyhistory/DATABASE%20World%20Energy%20Consumption(MALANIMA).pdf>

Temperature (Europe, aggregate)

- EEA.European Environment Agency. Global and European annual average near-surface temperature anomalies relative to the pre-industrial period 1850-1900.

<https://www.eea.europa.eu/data-and-maps/figures/global-left-and-european-land-2>

Temperature (European countries)

- <https://berkeleyearth.org/data/>

European GDP

- Eurostat. National accounts. Main GDP aggregates.

https://ec.europa.eu/eurostat/databrowser/view/ nama\_10\_gdp/default/table?lang=en&category=na10.nama10.nama\_10\_m

4. *Code*

The code is to be run in the logical order – as given:

enerdat. energy data

gdpdat. gdp (Ger, Fr, It, Sp)

gdpdat2. gdp2 (Neth, Po, Gr9)

popdat. population dat (Ger, Fr, It, Sp)

popdat2. population dat2 (Neth, Po, Gr9)

plyleley. plot ratios

wv. wavelets

wvls. wv analyses

pltacttrn. Plot trends

svm. svm estim.

plt3d. plot 3d

fcst. forecasting

fcstby. forecast beyond baseline

simfcst. forecst simul