A FRACTIONAL COINTEGRATION MODEL FOR THE ASSESSMENT OF CO2 MARGINAL EMISSIONS FACTOR (MEF) FOR THE ITALIAN POWER MARKET

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Overview

Climate change calls for the evaluation of the relationship between renewable energy production and greenhouse gases reduction. For the electricity sector, this requires evaluating the impact that electricity production from Renewable Energy Sources (RES) has on CO2 emissions. The simple measurement of the ratio between the emission of a given power system and the corresponding power production, i.e., the Average Emission Factor (AEF), ignores the structure of the generation mix in power system and neglects the dynamic change induced by RES on the merit-order. This prevents a correct measurement of the marginal impact on emissions of a policy that would affect RES production. To surmount this problem, Hawkes (2010) was the first to identify the Marginal Emissions Factor (MEF), i.e., the estimate of the sensitivity of carbon emissions to the levels of electricity generation and fuel mix composition.
In this paper, we estimate the MEF of the Italian power system. We build up on our recent findings included in the work by Burlinson et al. (2020) in order to address the following open issues.
Firstly, we shed some light on the zonal differentiation of MEF estimates, by capturing the geographic distribution of power plants which may eventually affect the different magnitude of MEF at the hourly level. This is relevant from a policy point of view, since we provide an estimation of zonal MEFs in order to assess the effectiveness of RES incentives at the zonal level.
Secondly, we take into account the time dimension of the data applying a robust econometric methodology that tests for the presence of a long memory behaviour in the emission and power supply data. We show that there are partial joint co-movements of emissions and generation in Italy characterized by a long memory, which calls for the use of the fractional cointegration framework (Johansen, 2008; Carlini and Santucci de Magistris, 2019; Nielsen and Popiel Ksawery, 2018). This approach extends the classic cointegration framework introduced by Engle and Granger (1987) by allowing the order of cointegration *d* to take fractional values.
Thirdly, we are going to estimate the impact of RES by assessing the overestimation errors of the “conventional” estimates of MEF (without the inclusion of RES in generation data) with respect to our “expanded” (with the inclusion of RES) measure of MEF (Li et al., 2017). This is relevant for policy considerations about technology adoption within a specific electricity grid and their impact over the decarbonization process.

Methods

We use hourly and zonal data about CO_2 emissions and electricity generation in 2018 to derive an empirical estimation of the MEF.
Following the procedure of Burlinson et al. (2020), we start by testing for stationarity and the presence of unit root for the seasonally-adjusted time series, in each physical zone. The analysis of ACF and PACF helps to identify the generating process of the time series. We consider the intra-day approach that uses the data of the hourly market settlements within the same day, capturing both the impact of shocks from the demand side (changes in load) and from the supply side (change of the power supply mix).
We compute the annual, seasonal and monthly MEF for each physical zone, modelling emissions and generation through the $FCVAR_{d,b}$ identification strategy.

Results

The unit root and stationarity analysis show the required evidence of the long-memory behavior of the time-series variables for all zones (lack of suitable data does not allow us to perform the analysis for zone South).
At the aggregate level, which does not take into account the different power mix across regions, the estimated values of MEF range between 0.5 and 0.65 tCO2/MWh (see Burlinson et al., 2020), with the AEF being equal to 0.537 tCO2/MWh.
The empirical estimation of yearly MEF for North equals 0.199 tCO2/MWh, significantly lower than the calculated value of the AEF at 0.284 tCO2/MWh. For zones Center North and Center South we do not find any presence of cointegrating relationships. In Sicily, which is one of the zones with the highest penetration of RES[1], the MEF amounts to 0.513 tCO2/MWh, significantly higher than the calculated AEF at 0.074 tCO2/MWh. Sardinia reports a value of MEF at 0.67 tCO2/MWh, which is more than double of the computed value of AEF that equals 0.3 tCO2/MWh.

Conclusions

The preliminary results of MEF estimation for electricity generation in Italy show that it is crucial for the policy makers to use MEF to drive policy interventions, and to take into account the zonal configuration of the market.
The variability of power generation, the dynamic mix structure of the marginal technologies dispatched by the System Operator (SO) according to the merit-order criterion and the carbon intensity of the marginal technologies represent the main drivers that affect the estimated values of MEFs.
The differences between the national MEF and the zonal ones need to be taken into account when designing a policy intervention. This is relevant for the case of Italy. For instance, a policy that would support the installation of PV power plants, which are widely diffused in North and South, would have an impact on CO2 which depends on the MEF of these zones.
This point is relevant for other markets/countries too, with a different geographical dispersion of RES, to evaluate the effectiveness of policies targeted at phasing-out thermal power production.

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[1] The daily penetration of RES ranged from 23% to nearly 80% in 2018 for Sicily. *Source*: our calculations.