By the end of September research plan + notes from papers + **data**

First draft end of November doesn’t be perfectionist. Find subject with available.

BEFORE 15 of December final version

Electricity prices: A lot of variation longitudinal, But not a lot during time. Need of long-time span

**Effect of RES on electricity prices volatility**

Endogeneity between RES presence and volatility (reverse causality). Use IV strategy to overcome this issue

Data:

[Electricity P](https://ember-energy.org/data/european-wholesale-electricity-price-data/) hourly, monthly, daily: 30 countries for 10 years

[ENTSOE](https://transparency.entsoe.eu/generation/r2/actualGenerationPerProductionType/show?name=&defaultValue=false&viewType=TABLE&areaType=CTY&atch=false&datepicker-day-offset-select-dv-date-from_input=D&dateTime.dateTime=09.08.2019+00:00|CET|DAYTIMERANGE&dateTime.endDateTime=09.08.2019+00:00|CET|DAYTIMERANGE&area.values=CTY|10YAT-APG------L!CTY|10YAT-APG------L&productionType.values=B01&productionType.values=B25&productionType.values=B02&productionType.values=B03&productionType.values=B04&productionType.values=B05&productionType.values=B06&productionType.values=B07&productionType.values=B08&productionType.values=B09&productionType.values=B10&productionType.values=B11&productionType.values=B12&productionType.values=B13&productionType.values=B14&productionType.values=B20&productionType.values=B15&productionType.values=B16&productionType.values=B17&productionType.values=B18&productionType.values=B19&dateTime.timezone=CET_CEST&dateTime.timezone_input=CET+(UTC+1)+/+CEST+(UTC+2))

**Production/load ratio**

Synthesis of literature, come up with new model, **derivatives or implementation of physical connections**.

H : renewable increase volatility

Put seasonal variation depends on the granularity (daily or hourly)

Price volatility doesn’t have time series problem

Estonia Finland : Fault on 26 Jan 2024 at 00:10 eet: The Estlink 2 link shut down due to an internal short circuit in the cable in late January. It remained out of operation until around end-August 2024. [Source](https://news.err.ee/1609560328/estonian-finnish-undersea-power-link-estlink-2-down-again-due-to-fault) [Fingrid](https://www.fingrid.fi/en/news/news/2024/failure-on-estlink-2-interconnection-26.1.2024/)

Important points: Structural brake since decoupling with Russian and Belarusian grid in February 2025. Second outage on 25 dec 2024. Control for these events in case of consideration.

If TSO curtailed renewable production, this endogeneity would fake the results. At least checks for production and jumps in the production wrt last year. Solution regress renewable production on cable dummy

Use time dummies for weekends, holydays, peak off peak, season

Instrument volatility on wind production and check weather loss of interconnection makes an effect using SCM OR Create pre and post fault dataset and apply to both quantile regression (for instance Tselika method)

Robustness check, use different volatility measures, increase treatment window (from +/- 30 days to the whole jan to aug). Placebo (fake outage). Leads and lags for outage dummies

Check demand response programs in Estonia

Literature:

A. Why is the study interesting? (which social issues addressed? what is known or less well known? what is novel either in terms of data or methodology? what is suggested by the results?)

B. What are the main data sources (main characteristics and how are they matched?)

C. Contribution to the literature

D. What is the identification strategy? (expectable biases and ways to deal with them)

E. What are the main results? (on which variable and which specification)

F. Are the results robust? (techniques and outcomes)

G. Lessons and way ahead? (main implications and extensions)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | B | C | D | E | F | Take home |
| Ciarreta et al 2020 | Weekly day-ahead EP from 01/2002 to 12/2017 on Spanish market OMIE | Investigating effectiveness of policies on volatility | GARCH[[1]](#footnote-1) since structural brakes in Spanish market | Stable regulatory policies decrease volatility even in high-share-renewables markets | Acknowledged that volatility affect investments (Reverse causality) | Check normality (Jarque Bera) and stationarity (ADF test) of the TS  Seasonality due to demand (temperature) |
| Maniatis\_Milonas\_2022 | Hourly data August 2012 to December 2018. Transformed to daily frequency (arithmetic mean)  **Forecasted** daily load, wind, solar  differentiate peak and off peak | Analyse wind and solar separately + Greek market + increase price cap | GARCH univariate in mean | During peak hours, wind and solar power generation decrease price volatility. Renewables’ output reduces the volatility of wholesale electricity prices when it is positively correlated with the electricity load. | \* |  |
| Kyritsis\_etal\_2017 | Daily data German 2010 to 2015. Not forecasted, differentiate peak and off peak | Differentiate wind and solar. Capture supply and demand forces | GARCH univariate in mean | solar power generation reduces the volatility of electricity  prices while it reduces the probability of electricity price spikes. On the  other hand, wind power volatility passes through to electricity prices  volatility, and introduces electricity price spikes |  | Electricity prices are always stationary. Mean reverting  Kwiatkowski et al. (1992) tests are used in order to test the  null hypothesis of stationarity. USE PENETRATION = POWER OUTPUT/LOAD |
| Rintamaki\_etal\_2017 | Forecasted hourly Wind only Denmark and Germany (wind+solar). Forecasted load, hourly cross border flows.  From 01/2010 to 12/2014 | Peak and off peak  Wind/load | Seasonal ARMA | Wind power output decreases daily price volatility in Denmark (wind speeds are evenly distributed throughout the day) .Relative to its average electricity demand, Denmark has high transmission capacity to the Nordic countries with large hydropower reservoirs, which may also explain Denmark’s reduction in daily price volatility. In Germany, however, there is an increase in price volatility because of greater  wind power output during off-peak hours. Moreover, Germany’s cross-border transmission lines are smaller relative to its average electricity demand, and it has limited access to flexible hydro generation.  Gas prices don’t affect volatility | \*Peak and off peak as defined, do not take into account precisely the true load curbe (3 peaks: morning, midday, evening)  Peak or offpeak just defines day and night hours | Replace missing values on forecasted TS with realised ones |
| Tselika\_2022 | Danish and German hourly data from 2015 to 2020  Forecasted Load, forecasted wind power | Panel approach using 24 hours as panel observation. Which counts time and cross-sectional dimensions. Abling the use of FE | Quantile regression using scale and location to estimate impact on mean on variance (dispersion) | wind generation increases (decreases) the occurrence of price fluctuations for low demand (high demand) in both countries. Meanwhile, in Germany, solar power stabilizes price fluctuations for high demand levels, stronger than wind. |  |  |
| Maciejowska 2020 | Hourly data ENTSOE Germany 01/2015 – 01/2018. From h to daily through mean, dividing peak (only working days) and non-peak hours | Differentiate solar and wind  Differentiate peak/nonpeak  Study for different level of LOAD | Quantile regression approach on distrib of EP | Solar stabilises EP regardless of load (also because solar shins mostly during load hours). Wind only if load is high | \* | Use IQR to measure volatility (P(90% quantile)-P(10% quantile))  Control for LOAD |
| Sapio 2019 | Zonal (6) wholesales EP from 09/2006 to 07/2015. Daily average from hourly values NO peak/non.peak taken into account |  | Quantile regression on quantiles of log of daily EP wrt demand, log fuel prices + CO2 cost, log residual supply index, log **forecasted** supply PV + wind and cable dummy. | Confirmed merit order effect. Solar greater impact lower quantiles (EP lower already)  Wind lower EP overall. Solar magnify volatility. Cable has lowered prices + volatility mitigation (lowered possibility to price spike) | Pre-post comparison due to exogenous shock, no control group, anticipation of the cable? Comparative case study |  |
| Becker\_etal\_2021 | Yearly gasoline prices (hourly too volatile) from 2000 to 2008. 2009 is treatment and to 2018 is post treatment | Extend fuel pricing regulation using SCM | SCM. Austria treated, Donor pool (11 EU countries) | Fuel Price Fixing Act reduced prices by 23% |  |  |
| Hamidreza et al 2007 |  |  |  |  |  | Measure variability of returns (log diff of prices) using 2 scenarios, daily aggregation and independent hours |

**Put in the report**

**INTRODUCTION**

<https://www.iea.org/countries/estonia/electricity>

Consumption : 8.26 TWh

Production : 5.45 TWh Heavily reliant on imports (Coal 35% so not flexible, Biofuels 22% flexible)

Solar: 1 TWh

Wind: 1.16 TWh

Germany consumption: <https://ag-energiebilanzen.de/daten-und-fakten/auswertungstabellen/>

Electrical connection

EE 🡪 LV : 1447MW (LV🡪EE : 1259MW) [Source](https://www.ceer.eu/wp-content/uploads/2024/04/C23_Estiona_EN.pdf)

EE 🡪 FI : 350 + 650 MW Estlink 1 + 2 Estlink 2 is about 20% of the Estonian power export capacity

EE 🡪 RU : Unknown (ENTSOE actual flows, 800MW in 2022, 738MW in 2018 mostly Narva-Leningrad) [Source](https://dashboard.elering.ee/en/transmission/) But in 2023 and 24, the exchanges were weaker at 500MW max.

Estonian renewable energy overview : In 2024 electricity produced from renewable energy covered 39 per cent of the total consumption last year. In 2024, wind energy accounted for 34 per cent of the total production of renewable energy. In total, 1,164 gigawatt-hours of electricity were produced from wind. Compared to the previous year, wind energy production increased by 70 per cent. 694 megawatts of wind.

The production of solar energy increased to 1,005 gigawatt-hours. As at the end of the year, solar production capacity has counted of 1,210 megawatts [Source](https://elering.ee/en/article/both-solar-and-wind-energy-production-exceeded-one-terawatt-hours-last-year)

Accordingly, high price volatility due to renewables requires sufficiently high levels of renewables generation and a strong relationship between prices and the supply of conventional electricity generation (Steeper supply curve). This means that the supply will shift in case of intermittency and the steep supply curve will rise the price of electricity.

In the intro : Electricity prices reflect the physical peculiarities and economics of the power system as these are captured by supply and demand forces. On the one hand, there is the instantaneous nature of electricity and

transmission constraints, and on the other the highly inelastic short-term demand (Sensfuss et al., 2008) and limited economic possibilities of large-scale storage rendering the behaviour of electricity prices special

and dynamic. Pricing

Electricity mix Estonia

The main advantage of using a quantile regression model is its ability to examine the relationship between electricity prices and RES across the entire price distribution. flexibility. Bunn et al. (2016) highlight the advantages of using quantile regression to explore power prices, characterizing it as a semi-parametric method that allows the inclusion of fundamental variables. They also state that it could be used as an alternative methodology to regime-switching models. Furthermore, quantile regression does not assume a parametric distributional form for the error term (Davino et al., 2013) and allows the investigation of nonlinear relationships among variables. From Tselika 2022

**LITERATURE**

1st put contribution

2 branches: exploiting time series techniques (SARMA and GARCH) and quantile regression CHECK WHETHER BOTH METHODS GIVE SAME RESULTS. TSELIKA test the two!!

Rintamaky, Tselika and Kyritsis argue on the importance of flexible and well-connected grid

Basically, high volatility if RES produces off peak and no storage/transmission line availability. Low volatility if RES are synchronised on peak and off peak periods or grid is flexible. OR when the market struggles to accommodate the fluctuating supply by renewable generation due to lack of flexibility (storage capacity, etc.), we would anticipate the effect from RES intermittent generation to vary when demand is low (high) and renewable sources supply is high (low).

**DATA**

Presents- display dataset

Finally, mean reversion is another specific characteristic of electricity prices, mainly driven by weather conditions (Koopman et al., 2007); it refers to the tendency of electricity prices to revert to a long-run level reflecting the long-run cost of electricity generation. STATIONARITY From Kyritsis etal 2017

Seasonality table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Price | Solar | Wind | Load |
| hours-of-day | Evident during morning (4-8) and evening (15-19) peak | Clear solar bell shape | Slightly higher during nighttime | Day-night |
| day-of-week | Low on weekends | Apparently higher on some days | Apparently higher on some days | Low on weekends |
| month-of-year | Low on spring, high in winter | Clear solar bell shape | High occurrence on wintertime | Low on warmer, high on colder months |

**MODELS**

|  |  |  |  |
| --- | --- | --- | --- |
| Specify price variability | Econometric model | Unit of observation | Assumptions |
| IQR = p0.9 - p0.1  Distrib of 24 hours, daily obs.  Maciejowska (2020) | Linear regression | Days (in case of Maciejowska (2020)  Weeks in case of panel |  |
| Calculate the standard deviation over one week (7 observations) for each hour of the day (Equation 8)  Zareipour et al 2007 | Linear regression | Days (in case of daily aggregation)  Weeks in case of panel |  |
| Location-scale  Where scale is a measure of dispersion (scale for normal distrib is the sd) | Methods of moments quantile regression | Panel so Days and hours because variability function is estimated | The scale term should be strictly positive for all observations, because should represents sd (>0) |

**CONCLUSION**

Policy recommendation

Ireland UK : On 8 September 2016, the interconnector had a fault that occurred during an annual maintenance at the converter station in County Meath. The maintenance was carried out by contractor ABB. The interconnector re-entered service on 20 December 2016 with a fully rated 500 MW import, however exports to the UK were still limited to roughly 280MW.[5] As of June 2017, the cable offered full capacity in both directions.

**Liberalisation of electricity market**

Topic – Is the European competitive market a mechanism which foster renewable energy development?

Literature:

[Electricity prices and public ownership: Evidence from the EU15 over thirty years](https://www.sciencedirect.com/science/article/pii/S0140988313000911?casa_token=UgN5gMmoDZIAAAAA:Q5M1aN71MPYW7jWcjxXbK3Kxw2FlHJDUx67XW3GiLjZnARKED8FzT_ezW7oKp0iOTULmZRthXLeH)

[Effect of market structure on renewable energy Development—A simulation study of a regional electricity market in China](https://www.sciencedirect.com/science/article/abs/pii/S096014812300811X)

[Modernise it, sustainabilise it! Swiss energy policy on the eve of electricity market liberalisation](https://www.sciencedirect.com/science/article/abs/pii/S0301421500001026)

**Time series**

Recent Lit: <https://doi.org/10.1016/j.jup.2022.101405>

Advice : Deflate electricity prices, remove taxes

Classify different power market structure in terms of liberalisation

(<https://doi.org/10.1016/j.eneco.2008.12.004> )

Use market opening share (<https://doi.org/10.1016/S1364-0321(03)00069-8> )

Data :

[EU Energy market indicator](https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_market/default/table?lang=en&category=nrg.nrg_market) 26-36 countries across 10-12 years

Indicator for competition is to use the **switching rate** across retailers, **Concentration** (HHI score), **entry and exit**

**Danish monthly data on electricity sector per municipalities from 2013 for 73 Grid areas**

WHICH prices!! Impossible to find price at municipality level.

Problems:

* Electricity prices are autocorrelated : Control for EP t-1
* Endogeneity: High prices affect liberalisation/market structure, which affects prices

Identification strategy:

IV: regulation affects market structure, **political parties (left/right)**

**Analyse the effect of the exposure of wholesale market / on renewable energy on final electricity prices**

Data: <https://jupyter.zazuko.com/electricity_prices.html>, <https://www.prezzi-elettricita.elcom.admin.ch/>

Literature: [The role of renewable energy sources in residential electricity prices: A club convergence analysis across selected European countries](https://www.tandfonline.com/doi/full/10.1080/00036846.2022.2137294)

**Does cooperative ownership boost growth of renewable energy sources? Empirical evidence from**

Danish Renewable Energy Act

Literature: [Adoption of renewable energy technologies in rural Tigray, Ethiopia: An analysis of the impact of cooperatives](https://www.sciencedirect.com/science/article/pii/S0301421517308029?casa_token=8x11qKPrPAwAAAAA:l9TfAMJOljIrmB5zWXU0hoEhz3NkPk8NcaHvtK5A59lHuTsb0KghmuxQoTeDNWFdimXn0JUFkpJl)

[The role of cooperatives in overcoming the barriers to adoption of renewable energy](https://www.sciencedirect.com/science/article/abs/pii/S0301421513008276?casa_token=taml3KcZoD4AAAAA:CANsjmBStF8jMC1aQkOnSWgNVaVRFeeScL_RGX6jsYKM2_gRywqo8sG3f8dTgYHBZFJ_lBVGfWmD)

<https://www.dora.lib4ri.ch/wsl/islandora/object/wsl:18943/datastream/PDF/view>

<https://ocdc.coop/wp-content/uploads/2024/01/Energy-Cooperatives-in-Selected-Countries-of-the-World_-Legal-and-Economic-Aspects.pdf>

[Financing renewable energy infrastructures via financial citizen participation – The case of Germany](https://www.sciencedirect.com/science/article/abs/pii/S0960148114001293?casa_token=nEO5O78RRZUAAAAA:fI9z8Z2DLDPgI5l7eftrnD-k-O4Nw1uSNOFO9CJxmAtl_jHq_auNkkRQ7wTvH8LxG6cbKMpztRHL)

<https://stateofgreen.com/en/solutions/middelgrunden-wind-turbine-co-operative-middelgrunden-vindmollelaug/>

<https://www.iea.org/policies/17800-denmark-community-ownership-of-renewables>

[San Gallen](https://www.unisg.ch/en/newsroom/new-research-project-investigates-the-relation-between-financial-participation-and-social-acceptance-of-wind-energy/)

Data: <https://www.envidat.ch/#/metadata/energy-cooperatives-in-switzerland-survey-results?search=Energiegenossenschaften>+

1. Generalized Autoregressive Conditional Heteroskedasticity : Capture volatility clusters [↑](#footnote-ref-1)