

Green Signals? Exploring price dynamics in Europe`s green energy certificate market

Working Paper

7. Umweltbundesamt HKN Fachtagung, April 2025

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Umwelt
Bundesamt

Agenda

1

Background and Motivation

2

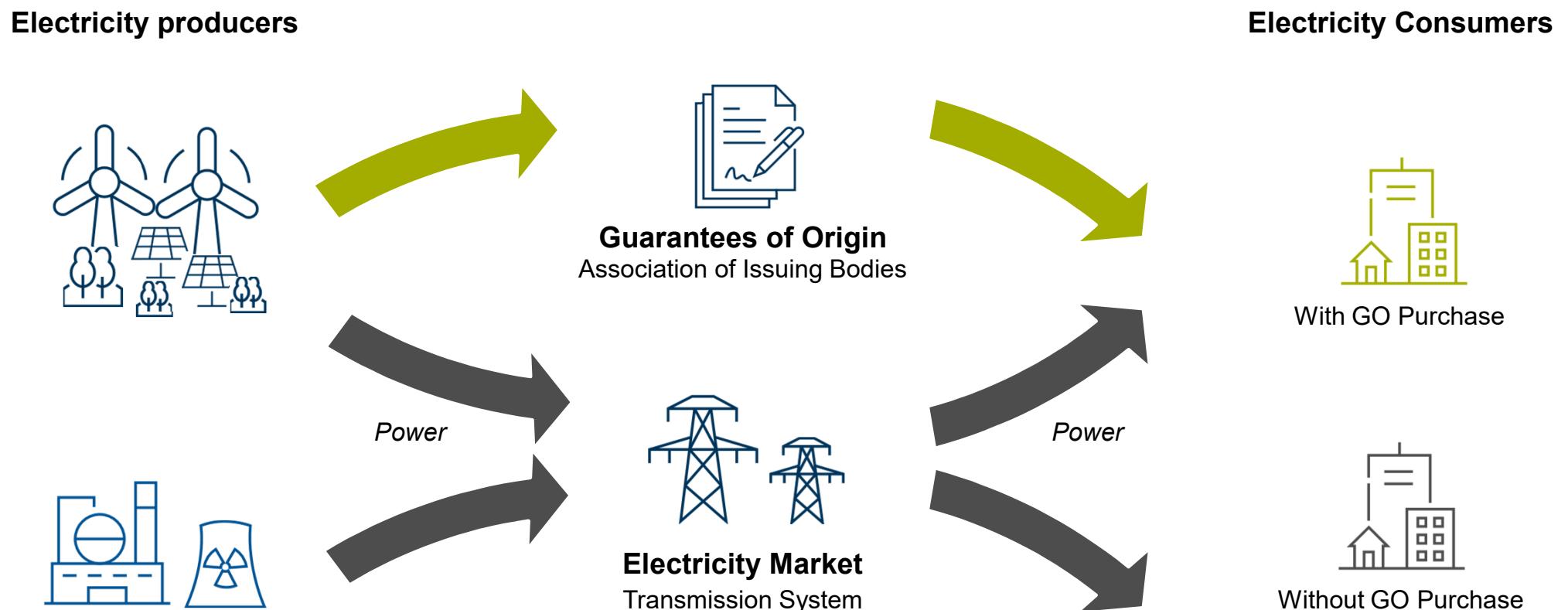
Research Question

3

Results



Background: Current GO market design allows for decoupling of two markets ...



... and thus, academic literature claims that GO prices fail to reflect value of green electricity

Dimension	Market Design	Criticism in literature
Geographical decoupling	<ul style="list-style-type: none"> GOs can be freely traded across AIB member states, independent of electricity flows Thus, GO “production” location, can be geographically distant from GO “consumption” location 	<ul style="list-style-type: none"> Abundance of Nordic hydro GOs is used in continental Europe to claim green electricity instead of local wind and solar GOs (Galzi, 2023; Hamburger, 2019; Mulder and Zoomer, 2016) GOs from different technologies become perfect substitutes, instead of being complements to regional electricity mixes (Hast et al., 2015) Thus, GO prices fail to reflect locational value of green electricity
Temporal decoupling	<ul style="list-style-type: none"> Current market design is based on “annual volumetric matching” Cumulative electricity volumes can be claimed as being “green” within a yearly disclosure period Thus, GO “production” time can be temporally distant from GO “consumption” time 	<ul style="list-style-type: none"> Insufficient stimulation of flexible renewable investments (Scholten and Blaschke, 2024; Xu et al., 2024) and effective grid decarbonization (Langer et al., 2024) Thus, GO prices fail to reflect temporal value of green electricity

1. AIB activity statistics (2024)

Agenda

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Despite abundant criticism of current GO system, there is a lack of real-world price data

Academic criticism

Dimension	Market Distortion	Critiques in literature
Geographical decoupling	European GDP price dynamics	Background and Literature
Temporal decoupling	European GDP price dynamics	Background and Literature
	... also reflected in recent literature ...	

It is “*unclear to what extent certificate markets function properly*” (Hulshof et al., 2019) due to lack of transparency of GO market

Associations and Industry initiatives criticism

About time: How incorporating timestamped energy certificates into electricity markets could accelerate the energy transition. Member States Must Move Quickly to Enable Granular GOEs

We urge EU Member States and Issuing Bodies to implement granular GOEs in their national legislative frameworks and ensure issuance by Issuing Bodies in a timely fashion. A European framework for timestamped energy certificates will enable the market to better value green energy, accurate price signals and enable the robust verification of green hydrogen and green electricity. This will be key to the success of the EU's climate and energy policies and the world's fight against climate and environmental degradation by 2050. By acting now, we can ensure a smooth transition to a sustainable future. We stand ready to support the transformation of energy origin tracking in Europe.

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- Introduction - "Fast"
- Time-based certificates
- Why is this important?
- Industry's role in the energy transition
- Example use cases for timestamped energy certificates
- Implementation
- Progress to date
- Implementation timeline
- Implementation partners
- Conclusion

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Two research questions aim to assess whether criticism is reflected in GO price data

Detailed methodology available on request

Research question	Rationale	Methodology
RQ1 Does the GO market show a price premium for solar and wind GOs over hydro GOs?	<p>Testing whether criticism of geographical decoupling is reflected in prices:</p> <ul style="list-style-type: none"> Trade without geographical restrictions leads and ability to substitute (mostly Nordic) hydro with solar and wind Gos Thus, prices across GO technologies converge 	<p>Analysis of GO price differences between technologies P_T (<i>solar,wind</i>) and hydro P_H across time periods:</p> <ul style="list-style-type: none"> Absolute deviations: $D_a = P_T - P_H$ Relative deviations: $D_r = \frac{P_T - P_H}{P_H}$
RQ2 Does the GO market show price elasticity to energy market fluctuations?	<p>Testing whether criticism of temporal decoupling is reflected in prices:</p> <ul style="list-style-type: none"> Annual volumetric matching reduces elasticity in response to supply and demand Thus, price signals to not reflect time-value of green electricity 	<p>VAR (vector autoregressive model) to analyze dynamic relationship between GO prices and supply and demand proxies:</p> <ul style="list-style-type: none"> $Y_t = \sum_{i=1}^m Z_i Y_{t-i} + e_t + c$ Supply and demand proxies: EU Electricity price and EU ETS prices (CO2 price) - (adapted to Schusser & Jaraite, 2018, Energy Economics)

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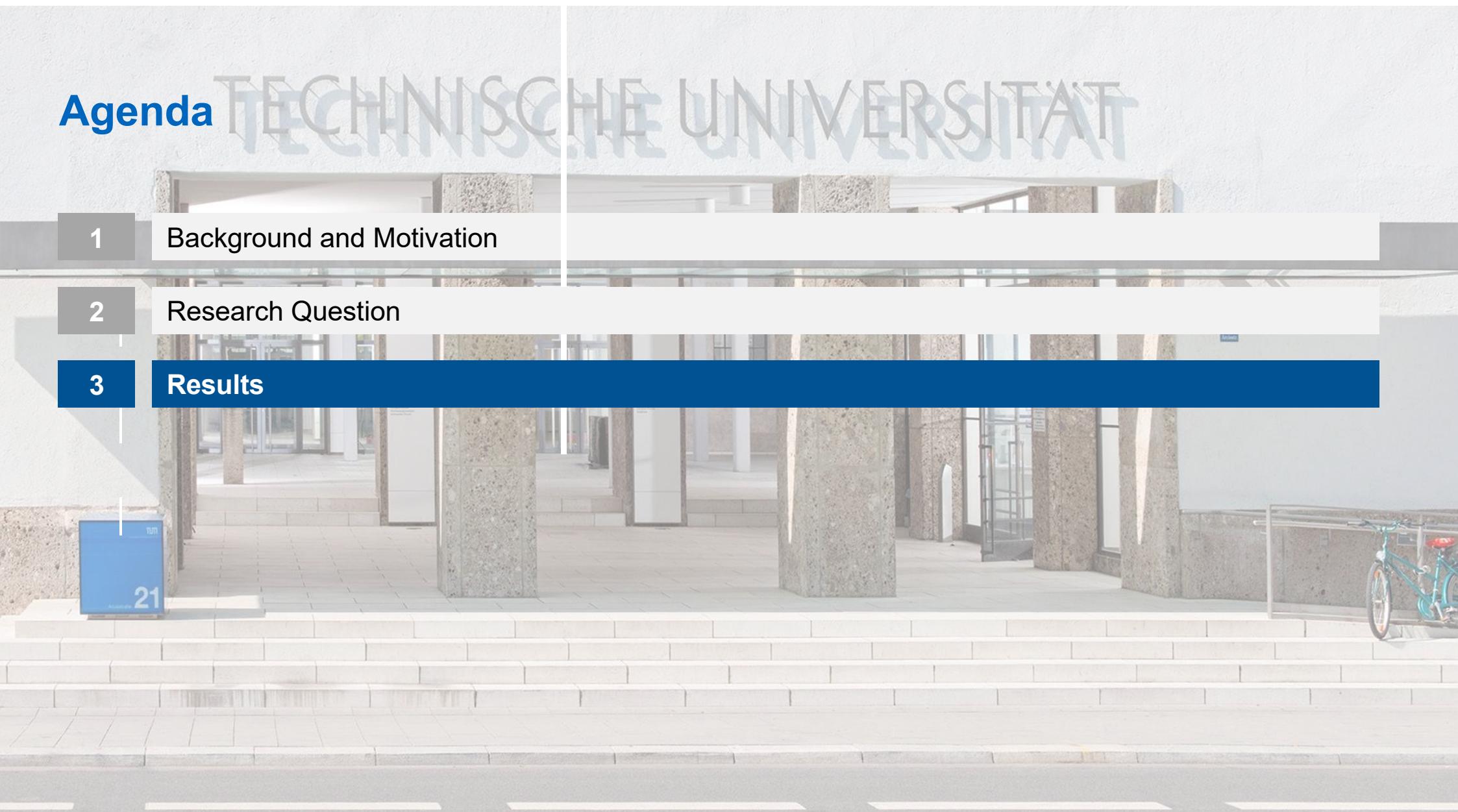
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Data deep dive: I obtained a proprietary GO price dataset from a leading market brokerage firm, allowing me to perform granular price analysis

Raw GO price data

1 transactionDateUtc 2 d_CY_vhydro_CY_bio_CY_vw solar_CY_vren-uns_C'ren_CY_vwap_weekly

transactionDateUtc	d_CY_vhydro_CY_bio_CY_vw solar_CY_vren-uns_C'ren_CY_vwap_weekly								
03.01.2016									
10.01.2016	26,25	14,25							
17.01.2016		20,0459							
24.01.2016		35,8721							
31.01.2016		37,5652							
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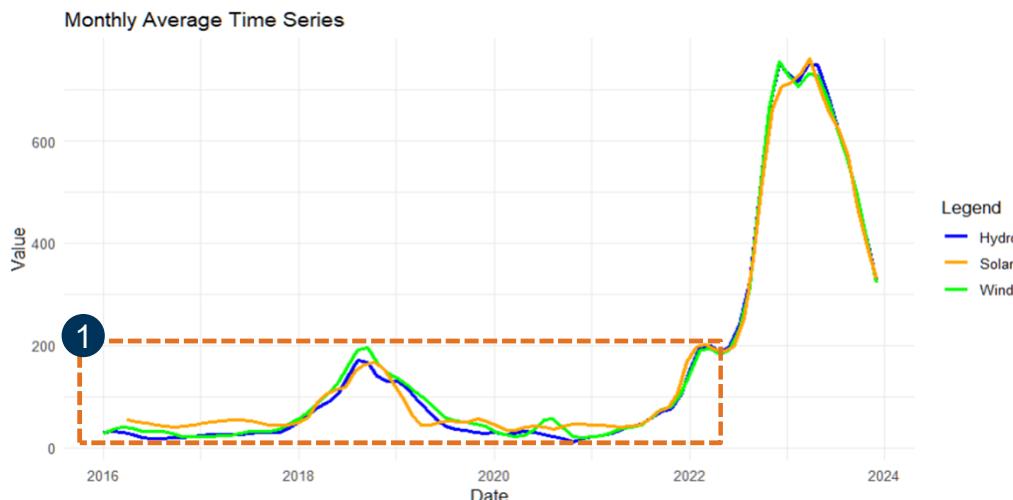
Provided by market intelligence
firm "Veyt"

Key Insights:

- 1 Data based on **weekly, volume-weighted average prices** in €cent/MWh base on real-world trades
- 2 Price available for **different “technologies”** (hydro, wind, solar)

Data not intended for sharing or reuse without permission of the author and Veyt

Analysis of descriptive data shows higher average prices for solar and wind GoOs, with absolute differences decreasing over time



Plot of monthly average prices per technology in €cents/MWh

Table 5: Weekly average GoO prices per technology 2016-2023

Technology	N	Min	Max	Mean	Median	Unit
Wind	285	13.0	963.4	188.7	87.0	€cents/MWh
Solar	157	23.5	831.5	239.9	100.0	€cents/MWh
Hydro	369	10.0	970.8	164.7	55.8	€cents/MWh

Summary statistics of weekly prices per technology in €cent/MWh

SOURCE: Own results

Key Insights

- 1 Visually, prices for solar and wind appear to be slightly higher until ~2022, converging afterwards
- 2 Average prices for wind and solar 2016-2023 higher for wind and solar compared to hydro

RQ1: Solar and wind GOs show price premium over hydro GOs – yet not stable over time periods

Key Insights

Solar and wind prices command a ~16-40% price premium over hydro GOs ...

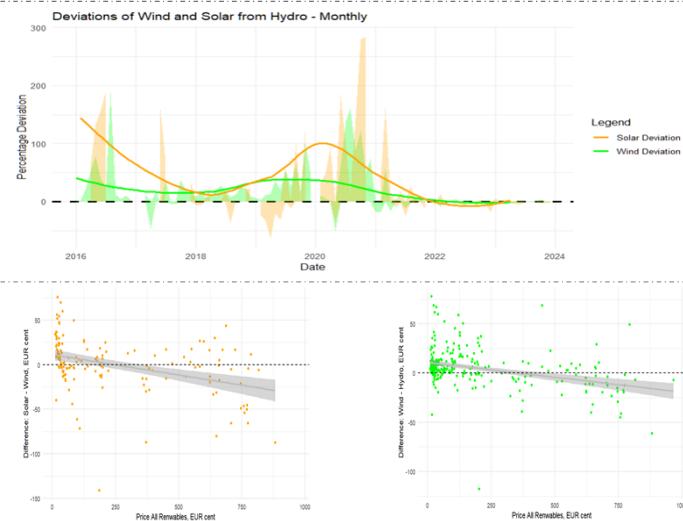
... with price **differences** varying over time ...

... tending to **converge** during times of higher prices

Analysis

Table 6: **Relative price premia solar/wind over hydro 2016-2023**
Table shows relative deviation of wind and solar GoO prices over hydro prices in %, for different aggregation periods

Technology	Monthly		Quarterly		Yearly	
	N	Mean	N	Mean	N	Mean
Wind	93	18.6	32	18.9	8	16.8
Solar	73	34.1	29	39.1	8	34.3



Discussion

- Market tends to value **solar and wind GOs more than hydro GOs** based on **long-term average values**
- Yet, **premium is not constant** and tends to collapse during periods of general high prices
- GOs from different technologies function as **substitutes during times of higher prices**
- Volatility and uncertainty around price premiums** for solar and wind could significantly dampen incentives for additional development of solar and wind assets

RQ2: GO prices show significant lag in response to carbon price shocks

Key Insights

To a positive shock in **electricity prices** (lower demand for GOs), GO prices react with a short negative response and lagged positive response...

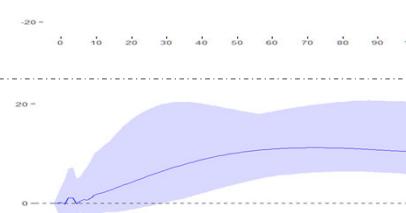
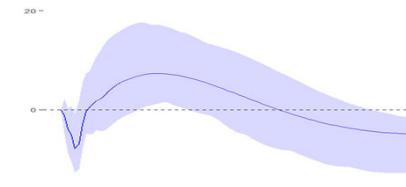
... indicating limited price elasticity

To a positive shock in **CO2 prices** (lower supply for GOs), GO prices react with a lagged positive response

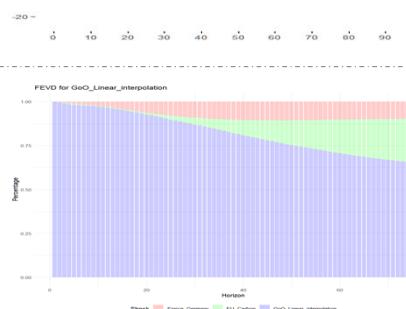
... indicating price elasticity in the theorized direction but with a significantly long lag

Both CO2 price variation and electricity price variations **influence GO price variations only marginally during first weeks**

Analysis



Impulse response functions for GO prices based on VAR model



Variance decomposition analysis

Discussion

- GO prices do react to movements in supply and demand proxies in **theorized direction**
- Yet, **significant lag in price reaction**, mainly to shocks in CO2 prices

➤ Demonstrates how **annual volumetric matching affects price signals**: Market participants do **not need to match GO purchases with real-time consumption**

➤ Thus, lagged GO prices **reduce incentives that could stimulate flexible** renewable capacities

Forschungsüberblick: Unser Paper liefert neue empirische Evidenz für geografische und zeitliche Entkopplung von GO Preisen



Hintergrund

- Kritik an geografischer und zeitlicher Entkopplung von HKN in Literatur
- Fehlende empirische Evidenz zur Frage, ob sich diese Kritik in realen Preisdaten widerspiegelt.
- **Ziel: Überprüfung, ob HKN-Preisdynamiken die Kritikpunkte stützen**



Ergebnisse

- **RQ1 (geografische Entkopplung):** Solar- und Wind-HKNs zeigen im Schnitt höhere Preise als Wasser-HKNs – aber kein stabiler Preisaufschlag über die Zeit.
 - **In Hochpreisphasen fungieren Technologien als Substitute**
- **RQ2 (zeitliche Entkopplung):** HKN-Preise reagieren auf Preisschocks in Strom und CO₂ Markt, aber mit signifikanter Verzögerung.
 - **Geringe kurzfristige Preiselastizität gegenüber Strom- und CO₂-Märkten**
- Belegt empirisch die Schwächen des aktuellen Marktmechanismus.



Mögliche Implikationen

- Neuer empirische Forschungsbeitrag
- **Granularere Zuordnung** (z. B. stündlich, regional) könnte Preissignale verbessern
- **Politische Entscheidungsträger sollten Reformbedarf** im HKN-Markt prüfen.
- **Marktteilnehmer könnten durch freiwillige Maßnahmen** (z. B. PPAs, lokale HKNs) Wirkung erhöhen.
- Grundlage für weitere Forschung
 - Granularere HKN-Daten
 - Zahlungsbereitschaft für granularen Grünstrom (Stated-Choice-Studie mit >1.000 TN in Arbeit).

