Enablers of hydrogen production: an econometric analysis

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Introduction

The global targets for emissions reduction compel governments in both high-income and developing countries to develop solutions for environmentally friendly industrial production without compromising their economic growth objectives. Given the significant uncertainty surrounding future climate change scenarios (IEA 2024), it is essential to explore, commercialise, and promote effective options for decarbonising the economy. Currently, the policy debate centres on green hydrogen as a potential technological breakthrough that could supplement existing low-carbon energy sources. Although global green hydrogen production is currently less than 1 Mt (IEA Global Hydrogen Review 2025), projections estimate about 38 Mt by 2030 (revised down from 49 Mt in the IEA Global Hydrogen Review 2024), with a target of 435 Mt in 2045 under a net-zero emissions scenario (IEA Net Zero Emissions Report 2021). These figures highlight the immense challenges countries face in facilitating an energy transition based on hydrogen.

Literature background

Research is rapidly developing on the drivers and bottlenecks related to the expansion of green hydrogen production.

The technical feasibility of green hydrogen production and technological progress represent a first important aspect of the discussion. Ampa et al. (2023) study the generation of hydrogen patents over the period 2000 – 2019 and identify the USA, China, and Japan as the global leaders; however, only more recently have new patents been based on renewable energy-based technology innovations.

With the growing scarcity of resources at the governmental level, the policy space to promote green hydrogen is shrinking over time. There is a growing need to shape appropriate policies for green hydrogen. Fell et al. (2023) set up a theoretical model to analyse the green energy transition. They find that optimal green hydrogen subsidies are positive if the unpriced externality from avoided natural gas is larger than the unpriced externality from electricity. Bade et al. 2024 analyze the USA market and identify the lack of specific regulations as the

main bottleneck for green hydrogen production. A recent contribution of Odenweller and Ueckerdt (2025) tracks 190 projects over three years and find a huge implementation gap, with only 7% of global capacity announcements concretely materializing. They emphasise that wider adoption of green hydrogen can only be achieved through aggressive carbon pricing and subsidies globally, which, however, are not currently based on realism. Therefore, Odenweller and Ueckerdt (2025) conclude that policymakers and stakeholders should be prepared for scenarios where green hydrogen is scarce.

Maka and Mehmood (2024) point out that lower production costs and the development of infrastructure and industrial scale remain important factors to scale up green hydrogen. The economics of green hydrogen and the related industrial capabilities needed for its production remain relatively underexplored topics in an already infant literature segment.

Emam and Özcan (2019) find that lower electricity prices of renewable energy could generate a positive impulse to the wider diffusion of green hydrogen technology and the consolidation of the related value chain. Building on the complexity literature (Hausman et al. 2014), a novel and developing strand in the green hydrogen research concerns identifying its development bottlenecks and enablers as well as economic aspects of the hydrogen production. Based on the product space technical toolkit, Müller and Eichammer (2023) design a methodology to estimate the capacity of world countries to export sophisticated goods relevant for the establishment of green hydrogen value chain. In particular, they identify a set of 36 technologies through which countries' bilateral trade exchanges can be analyzed and monitored over time. Inspired by their pioneering study, Amann et al. (2024) conduct an exploratory descriptive analysis on the capability of countries in producing and exporting goods that are crucial or relevant for the green hydrogen value chain. They find that high- and upper-middle-income countries are particularly well positioned in terms of enablers to produce green hydrogen. However, not all upper and high-income countries exploit their potential. In developing countries, the lack of industrial capabilities and the business environment constraints are crucial bottlenecks affecting the penetration of green hydrogen as a valuable energy option for future industrial development.

Research question

The present contribution further elaborates on the Amann et al. 2024 study by designing an econometric model to examine the factors affecting the current production of green hydrogen. This study fills an important gap in the literature by: 1) providing a new econometric analysis of the key enablers and bottlenecks to the expansion and consolidation of the green hydrogen value chain at the world level, including developed and developing countries; 2)adopting the new IEA data released in September 2025 for green hydrogen production and infrastructure; and 3) testing the robustness of the findings related to the development of green hydrogen with semi-parametric and non-parametric approaches.

Data and Methodology

The paper sets up an econometric model (parametric approach) to explain the current production of green hydrogen, such as:

$$y_{it} = \beta x_{it} + \varepsilon x_{it} \quad \epsilon_{it} = \alpha_i + D_{it} + e \tag{1}$$

where y is the production of green hydrogen of country i and time t, X is a vector of time variant explanatory variables covering the macro, meso and micro dimensions of green hydrogen production determinants, D is unit-year interaction explaining market and technology related developments, α_i is a unit intercept, e is the typical idiosyncratic error. A set of explanatory variables encompassing the macro (pertaining to the overall economy), meso (concerning the specific green hydrogen industry) and micro (concerning firms) dimensions stems from the importance of analysing the role of market fundamentals and industrial drivers affecting the production of manufacturing goods. Recent conceptual contributions further highlight the role of horizontal policies (aimed at improving market conditions) and vertical policies (aimed at addressing sector–specific bottlenecks) in steering the manufacturing development and capabilities (Hemphill, 2024). An estimation strategy based on macro, meso and micro explanatory variables is a quite common approach in the empirical literature (see Goldberg and Tille 2009, Nataraj 2011, Agostino et al. 2025). A unique feature of the study is that it would be the first one adopting IEA data on green hydrogen production, infrastructure and levelized production costs and the first of its kind in explaining the determinants of green hydrogen production from an empirical point of view. A list of potential explanatory variables of interest is contained in Table 1.

Results from the parametric approaches will be compared to those deriving from semi–parametric techniques (Machado and Silva 2019). More precisely, the linear specification for the conditional quantile of the dependent variable y and generic explanatory variables $\boldsymbol{x}_{it}$ is given by:

$$Q\big(\tau|\boldsymbol{x_{it}}, \beta(\tau)\big) = \beta(\tau)\boldsymbol{x}_{it} \tag{2}$$

where $\beta(\tau)$ is a vector of the coefficients related to the τth quantile. We estimate Equation 4 for τ = {10, 25, 50, 75, 90} and present the estimated coefficients alongside those of the canonical FE model obtained from Equation 1 in the next section.

Finally, a comparison with non – parametric techniques will further complement the paper model specification robustness tests (Simar 1992).

Table 1. Tentative list of explanatory variables of green hydrogen production

Variable	Data	Motivation	Dimension
Production of green hydrogen	IEA projects database	It is a variable that describes the current operational production of green hydrogen	Dependant variable
GDP constant prices	World Bank Development Indicators	The capacity to product goods and services in the overall economy could also explain the capacity to produce new energy related goods	Explanatory variable. Macro.
Manufacturing value added	World Development Indicators	Manufacturing value added expresses the capability of countries to produce industrial goods useful for the green hydrogen and related infrastructure production	Explanatory variable. Macro
Governance index	World Bank	A better governance facilitates diversification and the production of new energy and industrial goods	Explanatory variable. Macro
Infrastructure component of the Global Competitiveness Report	WEF	A national system of solid and reliable infrastructure is important to explain production capabilities	Explanatory variable. Macro
Green hydrogen infrastructure	IEA infrastructure database	The presence of key specific green hydrogen infrastructure such as pipelines, storage and transmissions is relevant to explain green hydrogen production	Explanatory variable. Meso
Revealed comparative	Mueller and Echammer list of	Mueller and Echammer (2023) identify 36	Explanatory variable. Meso

advantage in producing green hydrogen value chain goods	green hydrogen value chain goods and UNcomtrade statistics	trade goods representing the green hydrogen value chains and provide Harmonized Systems (HS) codes. With the UNComtrade statistics dataset, it is possible to track and monitor bilateral trade flows of these goods. The capacity to export goods related to the green hydrogen value chain with comparative advantage can be a driver of green hydrogen production.	
RISE (Regulatory Indicator for Sustainable Energy) index	World Bank	Specific capacity to regulate the energy system can be an important determinant of green hydrogen production	Explanatory variable. Meso
Levelized cost of green hydrogen energy	IEA	Countries with higher green hydrogen production costs are less likely to produce green hydrogen	Explanatory variables. Meso
Firms total factor productivity in the energy sector	World Bank	A higher country total factor productivity, as calculated by the World Bank Enterprise Survey database, represents the average country capacity at firm level to produce new industrial and energy goods	Explanatory variable: Micro
Bottlenecks to business in the energy sector	World Bank	The World Bank Enterprise Survey releases firms' data about the severity of bottlenecks to business for many	Explanatory variable: Micro

		world countries. Average values at country level can explain difficulties in diversifying towards new lines of energy production	
Other country, industry, firms, time fixed effects,		To capture different other forms of heterogeneity	Explanatory variable. Modelling.

Expected findings

The study promises to derive policy recommendations that decision-makers could consider for promoting the green industrial development agenda. Findings will be helpful to feed the dialogue about the development of green hydrogen as an alternative to fossil fuels for inclusive and sustainable industrial development.

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