Estimating Industrial Willingness-to-Pay for Hydrogen before the Market is There

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Overview

Climate change, exacerbated by anthropogenic greenhouse gas emissions (GHG), has necessitated a reevaluation of technologies in terms of their environmental impact. In this context, low-carbon hydrogen (H_2) has emerged as a crucial component in global efforts to reduce emissions across various industries. The versatility and potential of hydrogen to decarbonize hard-to-abate sectors, such as steel and fertilizer production, have generated significant interest in its role as an input factor aligned with net-zero transition goals. Advances in hydrogen production technologies have enhanced our understanding of its potential to substitute for fossil fuels, but the revealed high costs put strain on its adoption. Limited trade with opaque pricing, hidden in bilateral contracts, provides little information for market analysis. The lack of demand-side data precludes statistical estimations and hinders projections, resulting in uncertainty that poses a substantial barrier to the emergence and development of a hydrogen economy (Terlouw et al., 2024).

In this study, we take a challenging task of conducting a quantitative assessment of the willingness-to-pay (WTP) for clean hydrogen by an individual industry. Addressing the existing gap in current research, we propose a novel approach for empirical analysis and estimations of WTP for hydrogen based on the intra-industry international trade approach, integrated with industrial technology competition model. Our objectives are two-fold: (i) to develop a methodology that is applicable in any industry and country where hydrogen might be adopted as a substitute for fossil resources, and (ii) to demonstrate how the elasticity of hydrogen demand can be estimated, using industry production and material flow data, to examine at what prices hydrogen will scale up. The derived understanding of the WTP for low-carbon hydrogen is crucial for investors and industry stakeholders to assess the economic viability and financial potential of projects involving low-carbon hydrogen. Moreover, WTP estimations are particularly important for informing policymakers on how emission regulations or subsidies could accelerate the growth of hydrogen economy.

Methods

Focusing on sectors such as chemicals and metal processing, we begin our analysis by modeling industrial production as a function of feedstock prices, production efficiencies, and other pertinent parameters. To study the potential of hydrogen as a low-emission substitute for fossil feedstocks and to derive the willingness-to-pay for clean hydrogen (H2), we expand our model. We incorporating environmental regulation parameters and analyze the competition between fossil-based and hydrogen and renewable electricity-based production. Our goal is to develop an approach that ensures a nuanced understanding of how hydrogen can substitute traditional fossil feedstocks in the pursuit of a decarbonized economy.

Inspired by Shapiro & Walker (2018), who analyzed the role of marginal costs and international trade in emission reduction, along with environmental regulations, we model that domestically produced industry output, denoted as y, can be sold in the home market (y_{hh}) or traded in the world market (y_{hw}). Furthermore, drawing from international trade theory, we acknowledge that variations in feedstock prices and productivity can lead countries to both exporting and importing the same product. The imports from the world market to the home market y_{wh} are expected to affect both the home prices entering the demand function, and world prices for the output p_v due to the competition with other countries and home exports. Specifically, adopt Markusen & Venables (1998) linear (inverse) demand function with the slope parameter or elasticity dependent on the market size M:

$$p_h = \alpha - \frac{\beta_h}{M_h} \cdot Q_h \quad \text{and} \quad p_w = \alpha - \frac{\beta_w}{M_w} \cdot Q_w \tag{1}$$

and model the intra-industry trade and competition, solving it for the production levels to maximize their long-term profit:

$$\max_{y_{hh}, y_{hw}} \Pi^h = \left(\alpha - \frac{\beta_h}{M_h} \cdot (y_{hh} + y_{wh})\right) \cdot y_{hh} + \left(\alpha - \frac{\beta_w}{M_w} \cdot \sum_{i \in world} y_i\right) y_{hw} - mc_h \cdot y_{hh} - (mc_h + \tau) \cdot y_{hw} - F$$

We derive the optimal output as a function of home and world marginal costs and market sizes and the home price as a function of home and world marginal costs. Assuming that the marginal costs is a function of the fossil fuel prices, we convert the resulting euqations into testable hypotheses:

$$y_h^* = c_{y0} - c_{y1} \cdot M_w \cdot mc_h^{CH4} + c_{y2} \cdot M_w \cdot mc_w^{CH4} \text{ and } p_h^* = (c_{p0} + c_{pco2} \cdot p_{CO2}) + c_{p1} \cdot mc_h^{ng} + c_{p2} \cdot mc_w^{CH4}$$

With those estimates at hand, we are able to formulate the home industry inverse demand and use it to solve the competition between fossil fuels and hydrogen, deriving the WTP for hydrogen as a function of fossil fuel marginal costs, e.g., natural gas prices and conversion efficiencies γ:

$$p_h^{H2} = \boldsymbol{mc}_h^{H2}/\gamma^{H2} = \frac{3}{2\gamma^{H2}} A(p_w^{CH4}) + \frac{\boldsymbol{mc}_h^{CH4}}{3\gamma^{H2}\, c_{p1}} - \frac{2q_h^{H2}}{3\gamma^{H2}\, B}$$

The parameters A and B are the intercept and slop from the estimated and combined into $p_h(y_h)$ inverse demand. Hence, we proceed with the two-step estimations of WTP for hydrogen, envisioning its future use.

Results

We test for structural breaks and clusters in data and group the countries by their consumption to capacity ratio: importers, self-sufficient, small and large exporters. Running the regressions, we find that explicitly adding market size (population) we can avoid using time variable and can better capture domestic production driven by world prices and size in all the groups:

China & India production

	Coef	St. Err
c_{y0}	47636.09	1.76***
c_{y1}	-3.06	0.006***
c_{y2}	4.50	0.008***
Dummy c_{y2}	-1.70	0.001**
D_India c_{y0}	-40939.4	1.46***

Multiple R-squared: 0.96, Adjusted R-squared: 0.90

China & India price

	Coef	St. Err
c_{p0}	78.36	31.16**
c_{p1}	0.45	0.18**
c_{p2}	1.08	0.13***
Dummy c_{p1}	-0.39	0.15**

Multiple R-squared: 0.74, Adjusted R-squared: 0.65

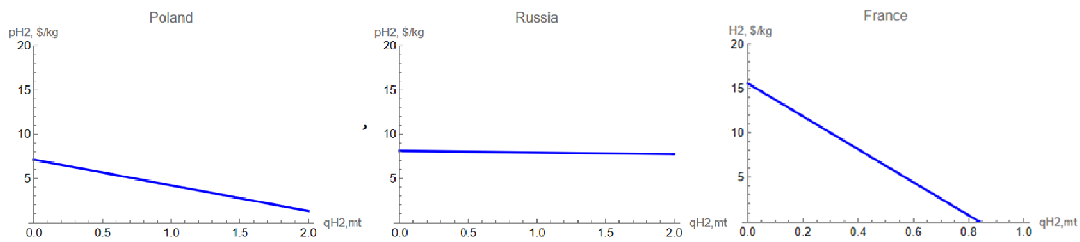

Figure 1. Preliminary results on domestic production and price estimations and resulting WTP.

Conclusions

We developed and demonstrated the validity of our 2-step approach for WTP estimations, confirming cross-country variability in willingness to pay for H2 to substitute fossil-based technologies. We find that CO2 price (just as a change in costs) has already started affecting the trade of fossil-derived outputs, with the cost changes passed through on production, rebalancing the natural gas use and attractiveness of H2. Our results suggest that exporting economies are focused on the relative rather than domestic prices and their H2 decisions. Our analysis highlights the importance of international trade considerations when the industry production in general and adoption of clean technologies, in particular, are analyzed. Finally, the results of our study call for further analysis including more countries and other industries, e.g., steel, and consider the pass-through effects with the global market.

References

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