INDUSTRIAL PLANNING WITH INPUT-OUTPUT MODELS: EMPIRICAL EVIDENCE FROM LOW-CARBON HYDROGEN IN FRANCE

Raphaël GUIONIE, Université de Nantes, LEMNA, raphael.guionie@.univ-nantes.fr
Rodica LOISEL, Université de Nantes, LEMNA, rodica.loisel@univ-nantes.fr
Lionel Lemiale, Université de Nantes, lionel.lemiale@univ-nantes.fr
Mathias Guerineau, Université de Nantes, mathias.guerineau@univ-nantes.fr

Overview

Energy industry represents roughly 2% of the GDP in energy importing countries (France, 2019). Yet any energy shock can lead to massive disruptions in the economy, since some energy vectors have features of General Purpose Technology and Source (Noce, 2015). We use input-output models to assess impacts on the French economy from substitution of imported natural gas with domestic low-carbon hydrogen. A new sector producing hydrogen is introduced to supply petroleum refining and ammonia sectors, based on domestic inputs exclusively. Two input-output models are built, a demand-driven model for the emergence of the H2 sector (investment phase), and a mixed model for H2 production (operating phase). Results show that the energy shock (350 kt of low-carbon H2 per year) generates significant growth (1 bln€ of GDP) and jobs (12,000), but needs ambitious planning for industrial development. Firstly, the investment phase triggers industries such as machinery and equipment, electrical equipment, construction and metal products manufacturing, suggesting that massive needs for labor requires more attractiveness to make the hydrogen infrastructure effective. Secondly, the hydrogen production being electricity intensive, the model shows very sensitive to this input and to the availability of power plants. At even higher shocks to remove all grey hydrogen in industry (415 kt H2) and steel production (700 kt H2), impressive domestic resources are required along with massive energy planning similar to the French nuclear program over 80s.

Methods

We focus on two major sectors traditionally using grey hydrogen: oil refining (CRP sector) and ammonia production (CC sector). In our model, these two sectors will consume domestic low-carbon (obtained through electrolysis with alkaline technology), instead of grey hydrogen from imported natural gas (obtained through steam reforming process). To this end, we build a two-stage input-output model (IOM) (**Fig. 1**). The first model is a demand-driven IOM aiming for capturing the economic consequences of the emergence of domestic low-carbon hydrogen sector, i.e. based on water electrolysis with low-carbon electricity (from renewables and nuclear). The second model is a mixed IOM which assesses the economic impacts of the H2 sector once the infrastructure is fully operational.

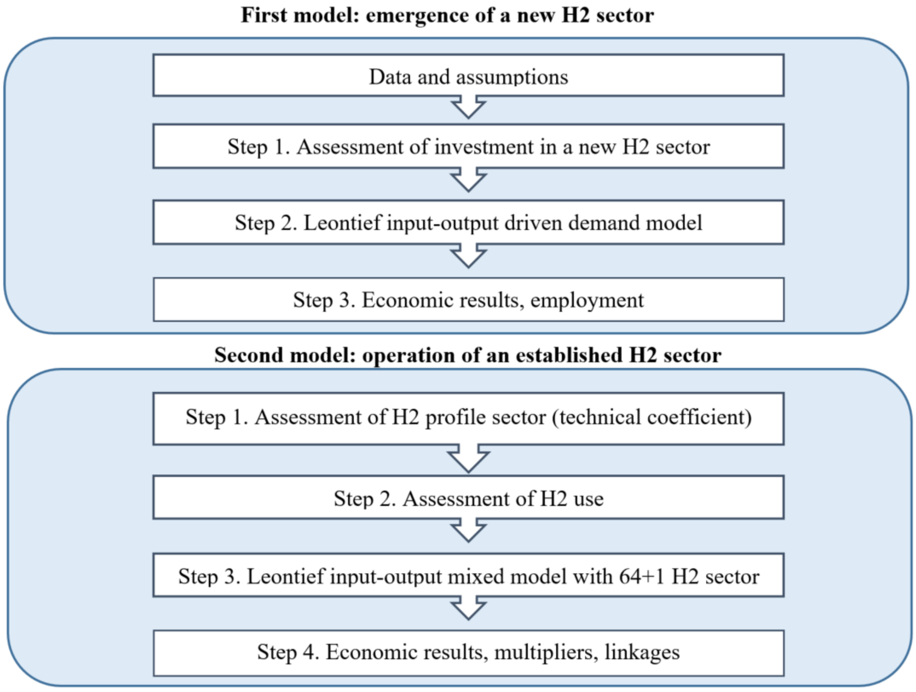

Fig. 1. Methodology flow chart

Results

First model (investment phase): substitution of grey hydrogen in CRP and CC sectors requires 350 kt of low-carbon hydrogen per year and about 2.1 GW of electrolysers operating at efficiency rate of 70% and load factor of 93% (RTE, 2021). At cost assumptions of 700 k€/MW for electrolysers (IEA, 2021), investment phase (final demand shock) is estimated at 1.47 Bln€ and generates a GDP of 1 Bln€ and around 12,000 of jobs. Main contributors to the GDP and to the aggregated output are industry-related sectors (machinery and equipment, construction, electrical equipment, fabricated metal product etc.). Jobs creation is also the highest in sectors related to the industry. This finding suggests that in order to successfully establish a domestic H2 sector, a national policy may be needed to attract workers, as generally these jobs have a poor public image, difficult working conditions and relatively low wages.

Second model (operating stage): The shock applied to the initial demand-driven model of 1,4Bln€ as CAPEX investment has built the H2 infrastructure that becomes operational at this stage. The current shock consists of a yearly exogenous production of 350 kt H2 which represent an annual production shock of 1Bln€ per year. Results indicate a GDP of 721 M€ and a total output (H2 plus inputs) of 3.2 Bln€, mostly from the electricity sector since hydrogen produced by electrolysis is electricity intensive. The shock reduces gas imports (16.5 TWh or 3% of total gas imports) and the energy bill (1.1 Bln € evaluated at 68 €/MWh). In terms of multipliers H2 holds a specific position. It ranks first for output multiplier (3.026), due to its specific activity focused on one good, hence not mixed with other energy vectors and due to its intermediate inputs that are supplied domestically. H2 sector has the highest Backward Linkage Indice (BLI)[1] which is quite expected as BLI is calculated by means of the output multiplier. On the Forward Linkage Indice (FLI)[2], H2 ranks 23th, meaning that the demand for H2 is relatively low in the economy. This result is driven by the assumption that hydrogen is used in two sectors only as intermediate consumption and not as final demand. However, this average FLI does not mean that H2 sector's output is not a dependant input for downstream industries, since a drop in H2 production could lead to a drop in CRP and CC output that stand at the beginning of the chain of intermediate products crucial for the economy.

Conclusions

This paper provided a methodological framework to address the issue of the energy security in France. We use input-output model to estimate first the human and material resources needed to build a domestic low-carbon hydrogen sector, and secondly to obtain hydrogen to supply two industries (ammonia production and oil refining). Results show that the H2 construction phase generates significant economic activity (1 bn€ of GDP over 3-5 years of building) and creates jobs (more than 12,000) and that during operation, the H2 sector largely relies on electricity as intermediate input, and generates around 5 M€ of GDP per year. Two main domestic vulnerabilities are created with our model, one upstream related to the availability of human capital during the construction phase and for H2 infrastructure maintenance, and one downstream related to the dependence of H2 on the electricity supply. Both issues require a high level of industrial planning and anticipation, firstly to make attractive industry for people again and to remove the negative image from the imbalance efforts to wage, in particular in sectors like machine building, electrical industry, chemicals, and construction. Downstream, the second issue is addressed by the capacity of the electricity sector to address this new demand for H2 production with electrolysis. Absent a massive electricity planning, a slowdown in the development of new power plants could threat our prospective scenario to sustainably produce domestic low-carbon hydrogen. Methodologically, input-output models contain intrinsic limitations due to linear calculation, a static representation of impacts of the transition, and exogenous innovation. Yet the model gives useful insights into the role that energy holds in the economy, and the cost-benefit structure from producing domestic sources (electricity) and vectors (hydrogen) that reduce the country energy dependence. As any industrial development, the State intervention is crucial at this stage.

References

IEA, 2021. Net Zero by 2050. Paris.

Miller R.E., Blair P.D. (2009). Input-Output Analysis: Foundations and Extensions. Cambridge, Cambridge University Press, second edition

Noce, A. A. (2015). Long-Term Economic Growth: Modeling the Race between Energy and Technology and the Stratospheric Effects of Hydrogen as a General Purpose Energy Source. PhD thesis, Concordia University.

RTE, 2021. Report on future perspectives in 2050, Chapter 9. The role of hydrogen and cross-sector coupling.

[1] BLI measures the potential for an industry to pull the other industries upward through its own intermediate consumption (Miller & Blair, 2009).

[2] FLI measures how much an output from a specific sector will induce attempts to use this output as inputs by others sectors for their own production (Miller & Blair, 2009).