Carbon risk and green steel investments: Real Options Analysis and MonteCarlo simulations to assess decarbonization policies

Simon Lang, EDF R&D,
Av. des Renardières, 77250 Écuelles, France
simon.lang@edf.fr

Frédéric Lantz, IFPEN
1-4 Av. du Bois Préau, 92852 Rueil-Malmaison, France
frederic.lantz@ifpen.fr

Overview

Steel is one of the most CO2 intensive material produced in Europe. Its production represents 4% of France's GHG emissions. Even though this industry has been quite protected from climate regulation, both the potential implementation of stricter policies and new technological progress are putting this 'hard-to-abate' industry under pressure. To meet EU decarbonization targets and quit coal, steel producers can rely on several decarbonization options: energy efficiency measures, heat recovery, incremental upgrading of existing assets (compatibility with biomass or carbon capture technologies), investments in new assets that use natural gas or hydrogen, or a shift towards recycled steel. Many challenges appear from this potential transition as producers would face both technological and commodity uncertainties. Firstly, current assets have a long lifetime varying from 30 to over 60 years, highlighting that an inadequate policy timing could result in either a lock-in with very emissive assets or stranded assets. Secondly, steelmakers would have to develop first-of-a-kind plants and be exposed to new energy markets, technological deployment risks and political uncertainty on the future CO_2 regulations. Lastly, investment needs are diverse and while some solutions have a high upfront cost, other investments can be spread over some decades or mainly results on an increase in operating costs. This results in a high uncertainty over the potential technological choices and the associated energy consumption.

Methods

To capture those challenges related to the decarbonization of the steel industry, we have used a compound real options framework with MonteCarlo simulations to model the future of the French primary production of steel. This model was adapted to a compound options problem as each investment changes the value of investments toward another one of the 12 technological solutions considered. This framework allows to represent the different transition costs associated with incremental or direct investment in low-carbon assets. Different options related to an investment are modelled:

- The option to defer an investment – the investment can be done later to wait for an uncertainty to unveil by expanding the lifetime of an asset through an increase of its maintenance costs
- The option to operative changes – some assets and incremental solutions allow to move from coal to biomass, which could be reverted temporarily if CO_2 prices drop. Another short-term substitution is between hydrogen & natural gas in a direct reduction blast furnace.
- The option to retrofit a plant – CCS (Carbon Capture & Storage), TGR (Top Gas Recycling) solutions expand the lifetime of an asset and its energy performances
- The option to invest in steps – H_2 solutions can be implemented in 1 to 5 steps

This results in a 12-lattices of technological solutions, from 2020 to 2070 to model choices made up to 2050. This lattice is then reduced by carbon budgeting practices trough the limitation of investment spending on the whole period. Carbon and other commodity prices are modelled as correlated geometric brownian movement, with different scenarios of decorrelation, drift and volatility depending on decarbonization hypothesis of the electricity mix. The carbon price is implemented trough a modelling of the main EU CO_2 policy- the Emissions Trading System (EU-ETS). This CO_2 market is subjected to great regulation uncertainty as its market design was heavily changed in the past decade. This is linked with potential technological risk scenarios of implementation failures thanks to a Poisson point process. Those uncertainties form the basis of the scenarios on which the Monte-Carlo simulations are done. For each scenario, and every point of the lattice an optimal investment sequence is calculated by a maximisation of the net present value using dynamic programming. This both include the certain cash-flow for the next year, and the actualised expected value of all potential assets depending on the anticipation of the stochastic commodities. Actualisations rely on comparing present and future cash-flows using a discount rate to represent the change in money's value. This value can change depending on many factors among which are: the actor's perspective (private or public), the interest rate and the risk factors that lead to its calculation, the cost of capital, the time preference, then anticipated future wellness. In a Net Present Value (NPV) framework, actualisation is set at the same discount rate for all investments, while the current RO framework only needs the risk-free discount to explicitly define the projects risks.

This work is the first to study compound real options in a Montecarlo simulation framework and as thus we exhibit some stability and validation parameters on the shape of the distributed perceived value.
From the optimal decision built for every scenario, at any point of the lattice, a more interpretable representation is constructed as the average optimal investment sequence. This framework also allows to assess the impact of Carbon for Difference (CfD), where the governments would derisk investments by guaranteeing a carbon or commodity price over the investment's life and reducing the volatility of carbon markets. Thus, different policies efficiency to reduce overall CO2 emissions and achieve the 2050 goals can be assessed.

Results

We show that carbon price volatility, considered with a fixed 2050 target, has a strong impact on investment decisions and might greatly increase the cumulative emissions by delaying investments in net-zero compatible assets. Common NPV framework with deterministic prices consider that a 200€/tCO_2 target in 2050 should be enough to motivate an investment in a hydrogen steel plant but as this breakeven point could be achieved too late, many blast furnaces would already have been refurbished at this point. Those analysis tend to still anticipate a great demand in coal in 2050. Our work shows that considering compound investments, a high rate of hydrogen plants is reachable if long term incentives are clarified. Nevertheless, adding volatility on the CO_2 price can result in coal lock-in through energy efficiency investments instead of investing in breakthrough technologies. This can be partially overcome thanks to carbon capture and storage or biomass use but would result in 2 to 3 times more emitting steel plants in 2050, and 3 to 6 times more CO2 emissions from 2020 to 2050. Natural gas reduction is a bridge technology to hydrogen, that make the investment cheaper in an uncertain environment, less risky and with a lower lock-in risk as it has fewer operational options.
Finally, the right combination of public support in the form of CfD and CAPEX subsidies is shown to vary a lot depending on the capital limitation and CO_2 volatility. Under a 5% volality, CfD have no noticeable effect, while they should represent between 60 to 70% of the public support scheme if volatility is over 10%. In all cases CfD have the particularity of being very cost effective compared to CAPEX subsidies that in some high volatility environments are associated with a high social cost of carbon and deadweight.

Conclusion

Governments have a panel of policies to decarbonize steel that have to be mobilized early while keeping the long term decarbonization goal as a clear target. CfD that includes bridge technologies appear as an efficient and cost effective tool in most scenarios seeing the challenges that the steel industry faces in an uncertain environment.

References

Gamba, A. N. (2002) "Real Options Valuation: A Monte Carlo Approach", SSRN Journal.
Vogl, V.; Åhman, M.; Nilsson, L. J. (2018) "Assessment of Hydrogen Direct Reduction for Fossil-Free Steelmaking". Journal of Cleaner Production, 203, 736–745.