THE MARGINAL ABATEMENT COSTS OF CO_2 EMISSIONS IN THE EUROPEAN CHEMICAL SECTOR

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Overview

This paper estimates the Marginal Abatement Cost (MAC) of CO_2 emissions for 25 firms in the European chemical sector in the period 2015–2020. We estimate the MAC using the quadratic directional output distance function (DDF) assuming firms' carbon abatement strategies are based on a good output-maximizing approach, which allows for the expansion of the good output and constant carbon emissions. We find an average firm-level MAC of 87 €/t CO_2 and find that the MAC is negatively related to the carbon-to-energy ratio (in t CO_2/MWh). Further, we plot the relationship between the MAC, the carbon-to-energy ratio, and other covariates for different regression model specifications and, using these estimates, construct a Marginal Abatement Cost Curve (MACC) to explain what factors drive the change in the marginal abatement cost of firms in the European chemical sector. Our MACC ranks the carbon intensity of firms (carbon-to-energy ratio) and the associated costs of emissions reduction (€/t CO_2) from lowest to highest marginal cost. The level of carbon intensity (determined by relative benchmarks) sets the marginal abatement cost (MAC; in €/t CO_2). Using the MACC, we infer firms' willingness-to-pay for different emission abatement options (e.g. electrification, hydrogen or biomass technologies), as the WTP for a given abatement technology is derived based on the difference between the observed MAC and the opportunity costs of switching to a given abatement technology.

Methods

This paper uses the directional distance function (DDF) and shadow price estimation method to estimate the MAC (Chung et al., 1997; Färe et al., 2005). This method assumes that the firm's production technology uses inputs to produce both desirable outputs and undesirable outputs. The shadow price (or MAC) of carbon is interpreted as the value of desired output that is foregone to reduce undesirable output by one unit, or the so-called 'marginal rate of transformation' between the two outputs, in order to reach the frontier of efficient firms in the sample. In this paper, the MAC is estimated by assuming that the direction in which the desirable and undesirable outputs are expanded and contracted, representing firms' production and emission abatement strategies, is asymmetric. That is, we assume that the desirable good is expanded and that the undesirable good is held constant, implying that we estimate the DDF using the directional vector $g = (1, 0)$. Hereby, we acknowledge that industries typically pursue energy efficiency and carbon efficiency improvements, rather than seeking to reduce absolute emissions by simultaneously expanding revenue and contracting carbon emissions to reach efficiency.

Suppose each firm in the European chemical sector employs two inputs, labor and capital (x_1 and x_2), to produce a desirable output (y), revenue, and an undesirable output, carbon emissions (b). Then, the quadratic DDF for firm i in year t can expressed as:

$$\overrightarrow{D_0}(x_{it}, y_{it}, b_{it}; g) = a_0 + \sum_{n=1}^{2} a_n x_{nit} + \frac{1}{2}\sum_{n=1}^{2}\sum_{n'=1}^{2} a_{nn'} x_{nit} x_{n'it} + \beta_1 y_{it} + \frac{1}{2}\beta_{11} y_{it}^2 + \gamma_1 b_{it} + \gamma_{11} b_{it}^2 + \sum_{n=1}^{2}\delta_{n1} x_{nit} y_{it} + \sum_{n=1}^{2}\eta_{n1} x_{nit} b_{it} + \mu_1 y_{it} b_{it}$$

where a_0, a_n, $a_{nn'}$, β_1, β_{11}, γ_1, γ_{11}, δ_{n1}, η_{n1}, and μ_1 are the unknown parameters to be estimated using the ddeterministic linear programming (LP) method by Aigner and Chu (1968). The shadow price (or MAC) of the undesirable output (q) is calculated using the price of the desirable output (p) as follows:

$$q = -p\left[\frac{\delta \overrightarrow{D_0}(x_{it}, y_{it}, b_{it}; g)/\delta b}{\delta \overrightarrow{D_0}(x_{it}, y_{it}, b_{it}; g)/\delta y}\right]$$

Subsequently, we regress the MAC on the ratio of energy use to revenues (energy-to-revenue, in MWh/€), the carbon intensity of energy use (carbon-to-energy, in t CO_2/MWh), and other covariates that may affect the MAC. Following Du et al. (2015), the regression estimates are used to construct the MACC.

Results

The results from our shadow price estimation are graphed in Figure 1, where we rank the firm-level MAC values from low to high. From the regression results (not reported), we find that an increase in the carbon intensity of energy use (carbon-to-energy ratio) relates to lower MAC values, while the energy intensity (energy-to-revenue ratio) is positively related to the MAC. One might expect a negative relationship between firms' energy intensity and MACs, as high energy users may have plenty of low cost (or low-hanging fruit-)options for emissions abatement. However, the energy intensity is not necessarily informative of the MAC: firms' may have high energy intensities while consuming energy sources with a relatively low energy content, implying that further emissions abatement would be costly. Therefore, we find that the carbon intensity of energy use is a better predictor of the MAC. In Figure 2, we plot the marginal abatement cost curve (MACC, see Du et al., 2015) in terms of the carbon-to-energy ratio.

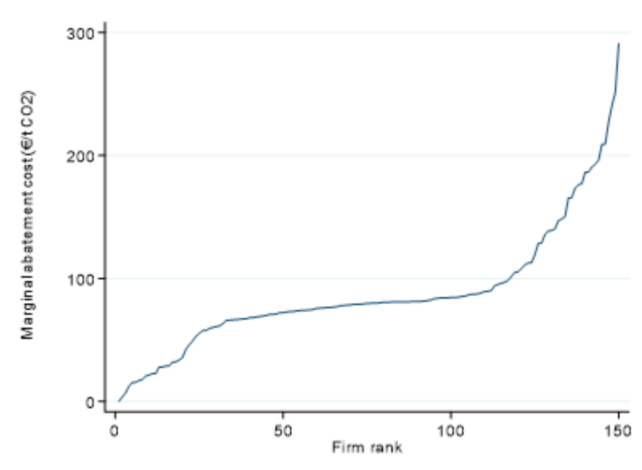

Figure 1. Firm-level marginal abatement costs (MAC, in €/tCO_2).

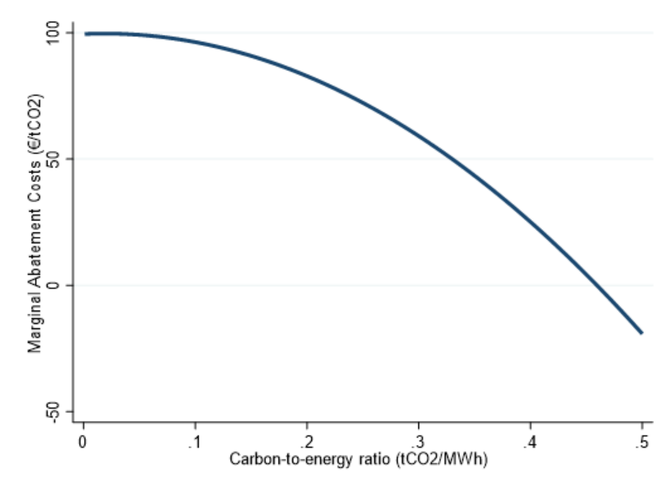

Figure 2. Marginal abatement cost curve (MACC) relating the marginal abatement costs (MAC, €/t CO_2) to the carbon-to-energy ratio (t CO_2/MWh).

Conclusions

Based on the shadow pricing framework, we find that the average marginal abatement cost (MAC) of firms in the chemical sector is 87 €/t CO_2. Further, we find that the carbon-to-energy ratio is negatively related to the MAC and is a better predictor of marginal abatement cost than the energy-to-revenue and the carbon-to-revenue ratio. In addition, we infer firms' willingness-to-pay (WTP) for different carbon emission abatement options from the marginal cost of abatement of the next best alternative on the marginal abatement cost curve (MACC). Here, the WTP for a given abatement technology is derived based on the difference between the observed MACs and the opportunity costs of switching to the respective abatement technology. A relatively low average MAC (compared to the cost of reference options) would indicate that there are many low-cost abatement options to be exercised within firms, and that there is a relatively low WTP for more expensive abatement technologies. On the other hand, a high average MAC indicates that there is a relatively high WTP for other abatement technologies. If policy makers find it desirable to promote specific carbon abatement measures, these findings may help to minimize the level of government taxes and subsidies for taking these measures.

References

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