



Marginal Abatement Cost, A Literature Review

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Abstract

Since the 1990s, articles have widely used MAC curves to analyse the best alternatives in terms of cost-effectiveness when deciding to abate a negative externality. Most of the articles are related to CO₂ abatement as the main externality to be reduced, and the main advantages and disadvantages of the MACC tool are presented in the literature review presented here. Finally, it is determined whether the curve is a definitive method for analysing and elaborating policy and business decisions or whether the tool needs to correct the methodology to increase the scientific consensus.

Keywords: abatement, externality, marginal cost, policy-making, MACC

1. Introduction

The European Union has set ambitious targets for tackling the externalities of road transport that require significant changes in the sector. This article analyses the situation of externalities related to CO₂ emissions and accidents.

In terms of greenhouse gas (GHG) emissions, the European strategy for road transport establishes a very ambitious plan because this type of transport is responsible for more than 70 % of the total emissions of the transport sector in the EU (*Figure 1*). This is why it sets two important objectives: for 2030, the sector's emissions should be reduced by 55 %; and zero emissions should be achieved by 2050.

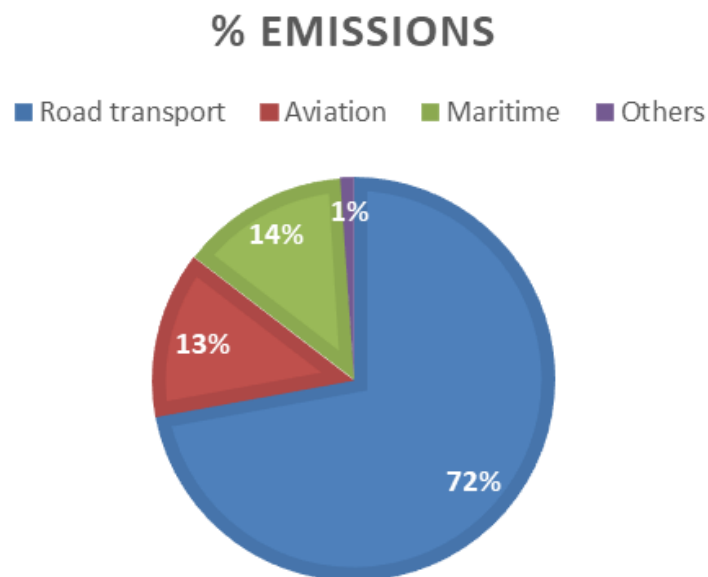


Figure 1. Transport-related emissions in the EU in 2020
Source: Eurostat

Regarding accidents, the European Commission's objectives focus on ending road traffic fatalities, with the objective of zero fatalities by 2050 as the long-term goal, while in the short-medium term, the aim is to reduce the number of casualties fatalities by 50% by 2030 compared to 2019 (*Figure 2*):

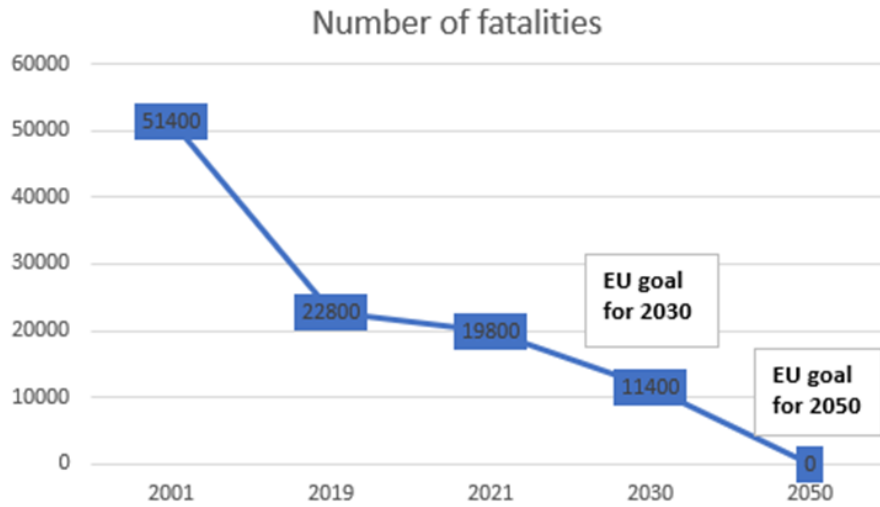


Figure 2. Changes in the number of road fatalities
Source: Eurostat

These ambitious targets set by legislators require aggressive measures in the transport sector to address negative externalities and achieve the agreed commitments. The sector’s transformation towards emission neutrality is a major challenge when defining the alternative that achieves the greatest reduction of externalities at the lowest possible economic cost. To answer this question, since the early 1990s, the “marginal abatement cost” curves began to be known as an effective tool for policies aimed at combating environmental and other externalities. This article reviews the literature on this subject to determine whether the marginal abatement cost curve (MAC curve or MCC) is a definitive tool for policy-making in externality reduction. This curve relates the cost of reducing an additional unit of externality (measured in tons of CO₂ if we are talking about pollution) to the reduction achieved in this externality. The diagram below shows how in recent years, the debate on the marginal abatement cost is closely linked to the transition towards more sustainable mobility (Figure 3):

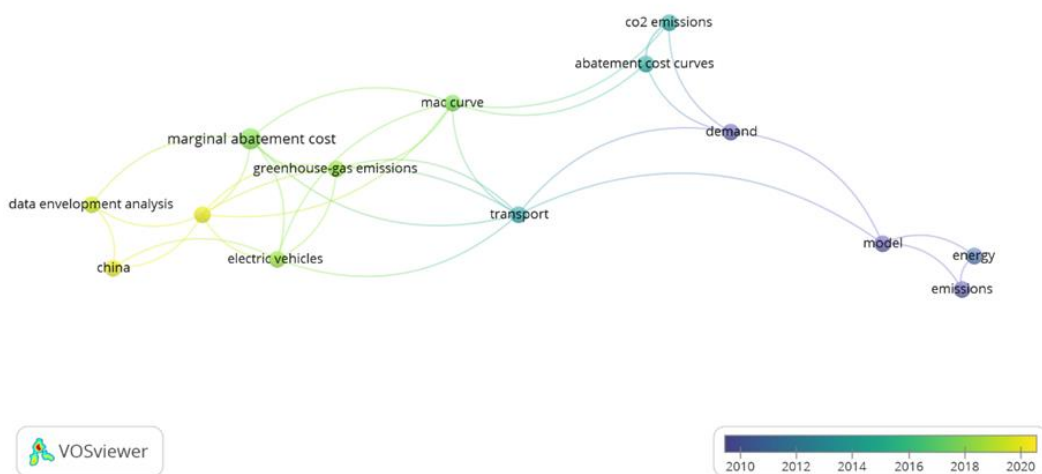


Figure 3. MAC curves
Source: Own edition with VoSviewer

2. MAC curves in environmental protection



There are two general ways to construct marginal abatement cost curves: a bottom-up approach using technical mitigation options; and the other approach to derive MACCs from computable general equilibrium (CGE) models (Wächter, 2013). In this article, I will focus on the most common bottom-up model in the literature. The MACC curve consists of three elements. The “y” axis is the marginal abatement cost measured in euros per unit of externality reduced. On the “x” axis, the volume of externality reduction achieved by each of the alternatives studied to deal with the analysed externality is represented. These technological alternatives, the bars on the graph, are the third element that allows us to analyse which technology achieves the most cost-effective externality reduction in a given period once the table has been constructed. An example of a MAC curve is given in Figure 4.

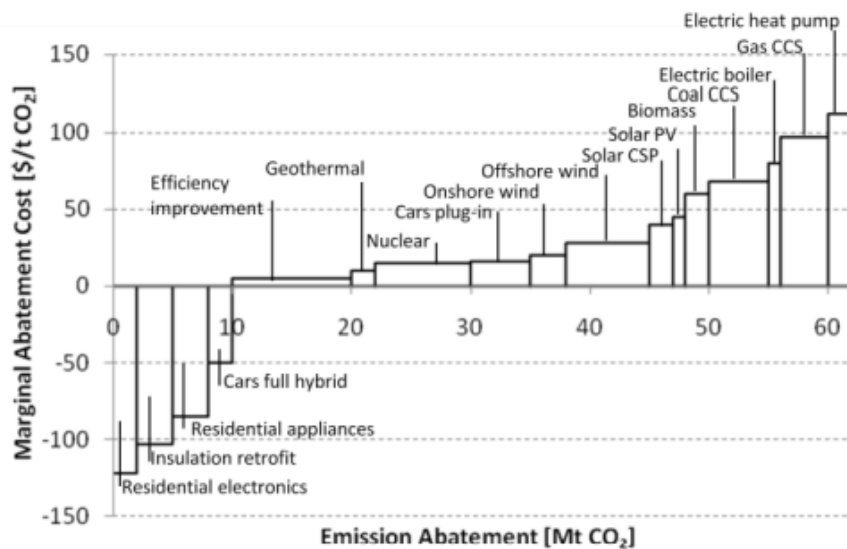


Figure 4 MAC curve example
Source: Kesicki, 2013

The three elements that make up the curve can be observed in this example of the most common MACC, the one used to analyse the most efficient technology for reducing pollutant emissions. If interpreted from left to right, the measures with the lowest marginal abatement cost are observed. Some even have a negative abatement cost, meaning they represent a saving and should therefore be the priority for solving the analysed externality. While on the other hand, the technologies that are further to the right will be the most costly to implement.

One of the most well-known methodologies for obtaining a MACC is regarding the analysis of each technology's Net Present Value (NPV), expressed by the following formula (Eq. 1). At first, the net present value of each technological alternative is calculated. It is divided by the amount of abatement achieved, multiplied by -1 to convert a negative cost into a positive one and vice versa.

$$(Eq. 1) \quad \text{€/tCO}_2 = \frac{NPV}{t\text{CO}_2 \text{ reduced}} \times (-1)$$

Where:
NPV: Net Present Value
T: ton
CO₂: Carbon Dioxide



3. MAC curves in road safety

With the signing of the Kyoto Protocol in 1997, countries were confronted with a target for reducing greenhouse gas emissions on the world political stage for the first time. It was in the 1990s that the literature related to MAC curves as a possible decision method for reducing atmospheric pollution began to be published. Previously, only a few studies related to oil prices could be found at the end of the 1970s. Using the WoS search engine, the 40 most relevant articles were analysed. The first relevant fact is that the same journal, *Energy Policy*, has published eleven.

Regarding the position of these articles on the MACC curve, the vast majority are limited to using the methodology to analyse the abatement potential in a specific industry or country, which can be considered an acceptance of the MACC methodology as an alternative with broad scientific acceptance, although most of the articles mention the limitations of the MAC curve (Fabian Kesicki, 2011), (Kesicki, 2011), there are only two articles among the 40 most cited articles that openly oppose the MACC methodology as a valid decision method. Kesicki and Ekins (2012) focus their criticism, especially on McKinsey's work with the following words, "it does not take into account interactions and the dynamic character of decarbonising the economy; it summaries average costs across a technology, though we know the variation in project costs within a technology can be much greater than variations between the average costs of competing technologies; it presents information about a single year's emissions, though they depend crucially on earlier abatement actions". Moreover, secondly, the article (Ward, 2014), criticises the methodology in its entirety. It claims that there is an error of interpretation since, according to its hypothesis, the alternative with the lowest marginal abatement cost is not always the preferable one to carry out. For this, Ward shows an example where the technological alternative with the lowest MAC value is the one that achieves the least amount of abatement. Thus, the conclusion is "Whilst MAC curves are just one tool used in assessing strategy, there remains a large risk of prioritising energy efficiency measures using an incorrect interpretation, which is likely to be wasting resources in the sub-optimal implementation of efficiency measures".

Within the literature on MAC curves, it is inevitable to mention the consultancy firm McKinsey, which since 2013 has carried out multiple studies on the MAC curve for many countries and sectors, primarily focused on pollution abatement. In addition to their work on environmental externalities, in 2013, they carried out a pioneering study on applying the curve to develop policies to improve road safety. This approach was a novelty, as this method was used for the first time to deal with a transport externality other than the environmental one. Following the curve methodology, the first step is to analyse the history of road accidents in a specific area to determine the reasons and design the alternatives that will be placed on the curve. This involves a preliminary fundamental analysis of the cost of each of these possible policies, which, together with an estimate of the reduction in accidents for each of them, makes it possible to analyse the cost of each measure in terms of the number of deaths it prevents and its cost to society.

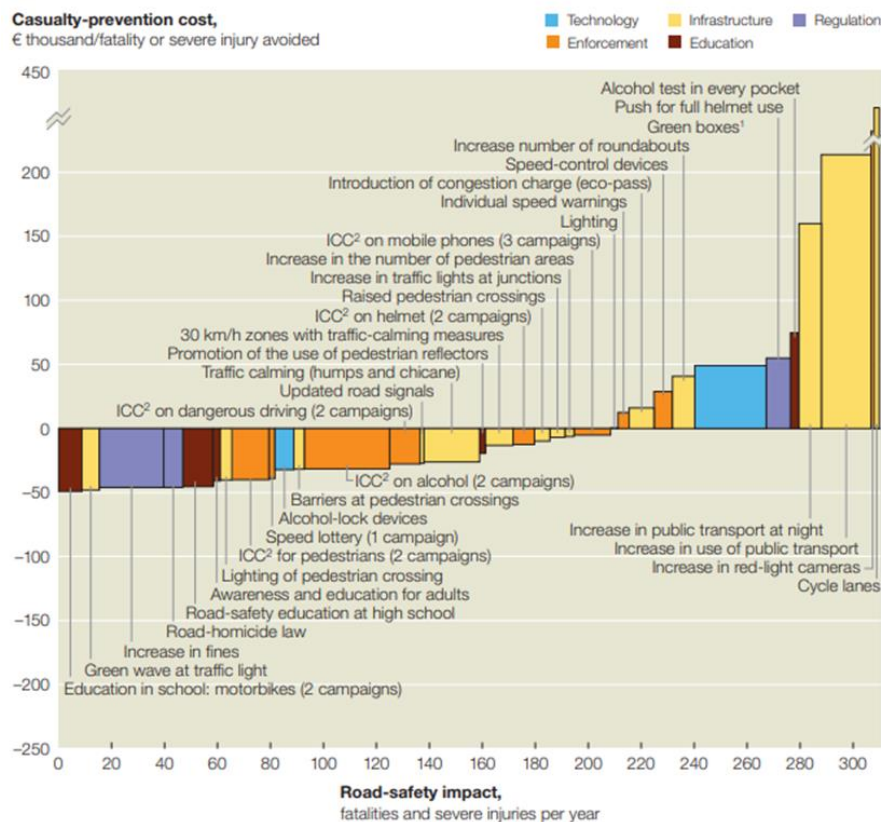


Figure 5 MAC curve example on road safety
Source: Ghislanzoni, Myerson, Ragani, 2013

Since McKinsey’s work, an increase in articles on OMC has been observed in the literature analysis. With China being the most polluting country in the world, it is understandable that five of the six most cited articles since 2014 deal with its situation. The literature includes abatement curves on coal-fired power plants on which China remains dependent (Limin Du, 2015), articles presenting the situation of emissions caused by industry in large cities such as Shanghai using a curve (X. Zhou, 2015), and others that address the issue of energy efficiency in the country’s buildings and its potential for the future as a tool for emission reduction targets (He Xiao, 2014) which concludes with an optimistic forecast “the annual CO₂ reduction potential of newly constructed buildings will be 214 million tCO₂, 42% of total potential by 2030”. These articles highlight the importance of MAC curves as a widely accepted method of policy decision-making in China. In recent years, the most cited works have focused mainly on coal abatement and the energy sector in various countries. However, a major difference is the absence of the classic MAC curve in all of them, transforming it into a more complex but analytical curve with greater mathematical support that responds to the evolution of the debate on the possible weaknesses of the McKinsey methodology. Articles that are focused on advice on decision-making on abatement reflect the new developments in its methodology to combat the static nature of the classic MAC curve; “this study involved a comprehensive analysis of possible developments and potential alternative pathways for GHG reduction for the transport sector and the first application of a cost-optimising energy system model for Gauteng. The presented method can also be applied to other socio-economic sectors or the whole energy system” (Tomaschek, 2015).

4. Conclusion

This article’s analysis of the existing literature on marginal abatement cost presents two main conclusions. On the one hand, most of the literature agrees on the tool’s usefulness as a practical policy decision method, but almost all of them also recognise its limitations and, therefore, the room for improvement. As strengths, the literature highlights the visual and easy-to-analyse approach provided by the curve to compare different technologies or policies. As a weakness, the most repeated one is the static character of the curve that does not consider the possible variation in energy prices. Therefore, in the conclusions of most of the articles, although the recent ones are starting to present interesting new methodologies for overcoming these weaknesses, the need



is expressed to continue developing the curve until a higher level of uncertainty is reached, which allows the MAC curve to be positioned as a method of broad scientific consensus in the development of policies to combat an externality is highlighted.

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