Approximation of abatement cost curve

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There is a conventional notion that elasticities of substitution are always estimated on the basis of historical data. It is a critical parameter in top-down modeling and it provides a good approximation of prospective technology options. When elasticities are estimated from historical data, there is no guarantee that the parameter values will remain valid into the future under different abatement policies (Jaccard et al., 2004). We propose a methodology to determine the elasticity of substitution on the basis of engineering studies. Instead of an econometric estimation, we calibrate a bottom-up cost curve.

Top-down models usually include piecewise-smooth functions to describe marginal cost curves, while bottom-up models describe those curves with a step function. When bottom-up cost curve is available, we can explicitly represent this curve with a top-down model in order to replicate its shape instead of using arbitrary assumptions. However, there is a lack of information about the range of alternative activities to which the producer can switch, implying that elasticity of substitution must be assumed. Judgments about the scope of substitution possibilities are discussed in Wing (2006) and Baker et al. (2008). We show how to identify the elasticity of substitution with bottomup data. The piecewise-smooth approximation method is explained using a pollution abatement sector, but our methodology can be applied to any sector characterised by decreasing returns to scale technologies.

Let us match the abatement schedule close to the middle point of step at the bottom-up curve. The objective is to minimize distance between the step and the smooth curves. The benchmark equilibrium describes prices and quantities at a reference point. Properly calibrated, this point will be the same in both the smooth and the step curves. The difference between the observed and the approximated abatement cost should be weighted with the pollution reduction achieved by the technical measure. This ensures that the technologies that reduce a lot of pollution are given sufficient weight in our algorithm.

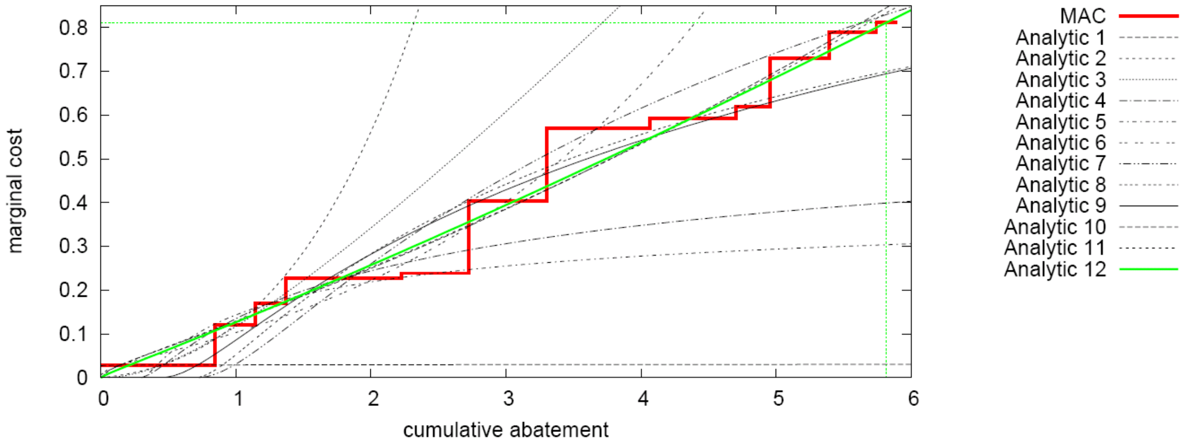

Figure 1: One of the method to minimize the weighted deviation from the bottom-up curve

The calibration of bottom-up curve will enable to portray the isoquant, but what functional form should we consider? Yu (2005) proposes to capture abatement activity similar to iceberg cost together with standard constant returns to scale production function. However, the abatement process is characterised by decreasing returns to scale technologies. For equilibrium analysis a function like constant elasticity of substitution (CES) is well suited for studying production process and it is relatively easy to calibrate. We consider a CES function and decreasing returns to scale. The best fit for the CES elasticity will be that which minimizes the weighted deviation from the bottom-up curve, as shown on Figure 1.

Our methodology is based on production function with a fixed factor. It allows us to simulate a decreasing returns to scale technology. The algorithm does not assume non-zero output level in the benchmark, unlike alternative algorithms. Four methods are discussed and compared: numeric fit, ordinary least square method, analytic fit, and hybrid fit. The first two methods are solved as a standard optimization problem. The third method is solved using a loop,and the forth method is a hybrid of the previous methods. The results of the approximation include the elasticity of substitution, the parameter that provides a good approximation of the technology options. Options which may never have been employed, but which are assume to exist on the basis of engineering studies. All four methods give similar precision, but the simplest is ordinary least squares.

A rational polluter, when faced with the necessity to reduce pollution, will first take the cheapest options and then turn to more costly ones. The marginal cost curve will therefore be non-decreasing. In addition, complete emission reduction is not possible via technical measures and a reduction of economic activity is required. Thus the cost curve approaches a vertical asymptote while the marginal cost approaches infinity. A discussion of the importance to analyze marginal, rather than total or average abatement cost is presented. We consider a combination of three cost curves to verify that targeted cost matters during the approximation procedure. We verify this hypothesis using abatement cost curves for greenhouse gases in the Czech Republic, Poland and Switzerland estimated by McKinsey & Company (McKinsey study, 2008, 2009a,b). The results for all three curves suggests that it does not matter whether we target marginal or total cost, but it might matter when average cost is targeted.

Finally, we address the issue of negative bottom-up cost. A McKinsey type cost curve gives the illusion that part of pollution abatement can be done for free. The construction of the cost curve implies that each action is independent from every other action and the probability of adopting is the same for all new technologies. A wide discussion of the free lunch problem can be found in Holmes (2010). We correct these negative costs using rescaling and compare three approaches, as results of top-down models are sensitive in this respect. In any event, below zero costs are inherently problematic.

An application of our methodology is straightforward: fitting an abatement function into a topdown model should improve the precision of the simulated environmental policies. Applying it into other sectors should also improve the precision of a top-down model. For example, Schaefer and Jaccoby (2005) get inconsistency between energy use with bottom-up and top-down models because their calibration procedure is not able perfectly match bottom-up data. With the methods that we propose, a perfect match should be expected.

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