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PERSPECTIVE

A grain of sand or a handful of dust?

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The recent paper by Girod *et al* (2013) analyses the implications of stringent global GHG mitigation targets for the intensities of, *inter alia*, broad consumption categories like food, shelter and transport. This type of scenario modeling analysis and inverse reasoning helps us to better understand the potential or required contribution of changes in consumption patterns to mitigation.

This is welcome because while there is a growing literature on the behavioral and consumption dimensions of mitigation, there is still no widely accepted framework for studying systematically the interactions between supply and demand, behavior and technology, production and consumption. So we are left with the question: what do we need to do exactly to stabilize GHG concentrations?

Intuitively, we take our cue from Aristotelian logic: if A implies B, then in order to avoid B we had better prevent A. At this level it is clear that we need either to decarbonize our energy systems to start with, or to suck out CO_2 from the atmosphere. When multiple causes are at work, however, our neat Aristotelian picture is no longer appropriate (Cartwright 2003). Leaving capturing and storage aside, we need to decarbonize our systems, but we also need to reduce the energy intensity, change our personal habits, eat less meat, use more public transportation, etc.

What is the right balance between these factors? Can we do just one thing, say, eat less meat, but not another, and still achieve some pretty ambitious mitigation goals? In other words, what are necessary and what are sufficient sets of measures to reach these goals?

Let us first look at the question of necessary measures. This gets tricky when applied to individual consumers: it is somewhat akin to the notorious question whether a heap of sand is still a heap when you take away one grain (Sainsbury 2011). If you are inclined to say yes, think once more. What happens when you take away another one, and another one, and another one, and so forth? Eventually you are forced call a single grain a heap.

By a similar type of reasoning none of us consumers makes any difference individually. It is tempting to conclude that therefore consumption side mitigation is not sufficient. But it also does not really seem necessary in the strict sense of the word as long as some supply side measure can compensate for a demand side measure not taken. Thus each one of us could go on as before, as long as someone else or some technology is compensating for our own failure to change. To be sure, such elusive argument is, to say the least, not very helpful, but it highlights the difficulty to derive very specific courses of action from aggregate goals.

So it takes a more prescriptive approach to get things going. The pragmatic mitigation wedge analysis by, e.g., Pacala and Socolow (2004) has highlighted that a relatively small number of dedicated and practicable measures is sufficient to achieve deep emission cuts, but the balance of these measures in the analyses is understandably somewhat arbitrary.

Other analysis, based on Integrated Assessment Models (IAMs) has focused more specifically on the questions of where and when measures would be

implemented in the most cost-effective manner. From such studies one can learn about carbon price trajectories, technology diffusion rates, and possibly about conditional probabilities for reaching targets over time. However, IAMs are rarely used to assess systematically the necessary or sufficient conditions for reaching a given target, and when they do the outcome often is—with the occasional exception—disappointingly generic.

Moreover, the controversies arising from value-laden allocations derived from IAMs are well-known: in these models emissions are typically reduced where it (supposedly) can be done cheapest, i.e. in low-wage countries, or according to some burden sharing scheme. The allocation of mitigation over time is essentially determined by the magnitude of the discount rate and thus a valuation of future versus present expenditures.

Refreshingly, Girod *et al* (2013) discuss a selection of allocation schemes across sectors, including consumers, that allow us to get an impression of the requirements and bounds for each of a set of stylized demand activities within the context of a plausible overall IAM story. Thus Girod *et al* (2013), make progress in addressing consumer behavior in the context of a wider set of activities contributing to GHG emissions and technological options to reduce these, without being committed to any particular allocation scheme.

Further work will have to address issues raised by a recent study (Schweizer and Kriegler 2012) on the limitations of the scenario space in earlier IPCC assessments to avoid past omissions. Moreover, IAMs in general need to become more transparent and more responsive to the needs of stakeholders. They also need to be applied specifically to identify concrete incentives, such as co-benefits of mitigation (Wagner 2012) and mechanisms (beyond stylized carbon markets) that nudge us towards low emission pathways.

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