LETTER

REPLY TO VAN DEN BERGH AND BOTZEN:
A clash of paradigms over the role of carbon pricing

Daniel Rosenbloom[a,1], Jochen Markard[b,c], Frank W. Geels[d], and Lea Fuenfschilling[e]

We welcome van den Bergh and Botzen's (1) comment on our paper (2) as it reflects foundational differences between mainstream economics and sociotechnical transitions perspectives on the role of carbon pricing (CP) in climate policy. Emerging from in-depth empirical studies of transitions in societal systems such as energy (3), the latter perspective is part of an ongoing shift in climate policy (4) toward "green industrial policy" and away from the market-based reasoning that has, to date, made little progress in solving the urgent sustainability issues at hand. Our reply centers on three core points that illuminate important differences between these paradigms.

First, van den Bergh and Botzen argue that markets and CP are systemic as they affect all actors and sectors. However, markets cannot be equated with sociotechnical systems that encompass broader elements such as long-lasting infrastructures (e.g., roads and pipelines), technological capabilities, cultural conventions, routinized consumption practices, and regulatory institutions, which are difficult to change with CP. While van den Bergh and Botzen reduce human action to resource allocation decisions in response to price incentives, the sociotechnical transitions literature emphasizes that system change also includes other (inter)actions such as technological experimentation and learning, sociocultural debates and sense making, and infrastructural system building (e.g., government-led buildouts of highways), along with political conflict and struggle (5).

Second, van den Bergh and Botzen claim that CP is critical to innovation. While this may be true within the stylized assumptions of the mainstream economics paradigm, this claim is unsupported by the empirical evidence indicating that the development and diffusion of crucial low-carbon solutions such as photovoltaics, wind energy, and electric vehicles have been principally driven not by CP but by technology-specific deployment policies and green industrial policies (see ref. 6 for a good example relating to solar). Such policies also help to create new actor coalitions that push for more ambitious climate policy over time, unleashing positive feedbacks (7). Nevertheless, many economists discredit broader climate policies as inefficient, an argument which has even been strategically leveraged by incumbents seeking to stall low-carbon transformations (8).

Third, van den Bergh and Botzen's trust in CP rests on idealized assumptions about the conditions surrounding climate policy. For example, they require that all countries implement a unified CP framework, which is politically unrealistic in the required timeframe (9). Their assumption that CP will be implemented in all sectors and industries also overlooks our initial argument (2) that CP may function well in sectors like electricity where alternatives exist and emitters cannot "escape" but is more difficult to implement in agri-food, transport, and heavy industry. We therefore proposed a sustainability transitions policy approach, which consists of a policy mix that stimulates radical innovation and far-reaching transformation, evolves over time, and is sensitive to sectoral context and political conditions (2). This mix may include CP, but CP should not be the dominant instrument.

In summary, our disagreement with van den Bergh and Botzen boils down to a clash of scientific paradigms. To achieve far-reaching low-carbon system transformations, climate policy needs to be based on new approaches rooted in sociotechnical transition studies and green industrial policy (10, 11).

1 J. van den Bergh, W. Botzen, Low-carbon transition is improbable without carbon pricing. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 23219–23220 (2020).

2 D. Rosenbloom, J. Markard, F. W. Geels, L. Fuenfschilling, Opinion: Why carbon pricing is not sufficient to mitigate climate change—and how "sustainability transition policy" can help. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 8664–8668 (2020).

[a]Department of Political Science, University of Toronto, Toronto, ON M5S 3G3, Canada; [b]Department of Management, Technology and Economics, ETH Zurich, 8092 Zürich, Switzerland; [c]Institute of Sustainable Development, Zurich University of Applied Sciences, 8400 Winterthur, Switzerland; [d]Alliance Manchester Business School, University of Manchester, Manchester M15 6PB, United Kingdom; and [e]Centre for Innovation, Research and Competence in the Learning Economy, Lund University, 221 00 Lund, Sweden

Author contributions: D.R., J.M., F.W.G., and L.F. wrote the paper.

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[1]To whom correspondence may be addressed. Email: daniel.rosenbloom@utoronto.ca.

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3 A. M. Arranz, Lessons from the past for sustainability transitions? A meta-analysis of socio-technical studies. *Glob. Environ. Change* **44**, 125–143 (2017).
4 J. Meckling, B. B. Allan, The evolution of ideas in global climate policy. *Nat. Clim. Chang.* **10**, 434–438 (2020).
5 F. W. Geels, Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. *Technol. Forecast. Soc.* **152**, 119894 (2020).
6 G. Nemet, *How Solar Energy Became Cheap: A Model for Low Carbon Innovation* (Earthscan, London, 2019).
7 J. Meckling, N. Kelsey, E. Biber, J. Zysman, CLIMATE CHANGE. Winning coalitions for climate policy. *Science* **349**, 1170–1171 (2015).
8 J. Markard, D. Rosenbloom, Political conflict and climate policy: The European emissions trading system as a Trojan Horse for the low-carbon transition? *Clim. Policy*, 10.1080/14693062.2020.1763901 (2020).
9 R. O. Keohane, D. G. Victor, Cooperation and discord in global climate policy. *Nat. Clim. Chang.* **6**, 570–575 (2016).
10 F. W. Geels, B. K. Sovacool, T. Schwanen, S. Sorrell, Sociotechnical transitions for deep decarbonization. *Science* **357**, 1242–1244 (2017).
11 M. P. Hekkert, M. J. Janssen, J. H. Wesseling, S. O. Negro, Mission-oriented innovation systems. *Environ. Innov. Soc. Transit.* **34**, 76–79 (2020).