TIPPING POINTS

Tipping points are thresholds that when crossed, cause a system to significantly change its behaviour. When a system is close to a tipping point, a small 'push' can lead to a large change.

In the climate system, tipping points are dangerous, because our desire is to avoid large-scale change. In the low carbon transition, tipping points can be helpful, because our aim is to achieve rapid and large-scale change, and ideally to do so in a way that makes the most effective use possible of whatever political and economic resources we have.

In most technology transitions, perhaps all, there is a tipping point: a point at which consumers decide that they prefer the new technology to the old; businesses focus their efforts on competing to make and sell the new technology instead of the old; and investors decide that the new technology is likely to be more profitable than the old. When this point is crossed, the transition tends to accelerate. This can be a useful point to aim for in the transition from fossil fuels to clean technologies in each of the greenhouse gas-emitting sectors of the economy.

A guide to policy stringency

A common recommendation on the stringency of climate change policy is that a carbon price should be set at a level equal to the economic value of the damage done to society by each tonne of carbon emissions. There are two problems with this approach. One is that the value of the damage done by climate change is both uncertain and subjective; consequently, estimates vary by orders of magnitude. The other is that this approach takes no account of the likely effectiveness of the policy in achieving structural economic change.

Tipping points provide a different way of thinking about policy stringency. The most simple approach is to consider what level of tax or subsidy is required to make a clean technology cheaper (or more profitable) than a fossil fuel, within a given sector.

Example 1: the world's fastest power sector decarbonisation

In the UK, beginning in 2015, a fixed carbon tax of £18 per tonne added to the carbon price of an emissions trading scheme made coal power more expensive than gas power. This happened in the context of renewable technologies, supported by targeted subsidies, providing a growing share of electricity generation, forcing coal and gas to compete over a shrinking share of the market. The crossing of this threshold swapped the positions of coal and gas in the merit order, so that instead of coal generating first, with gas only generating when demand exceeded what coal could supply, the reverse became true. This helped to tip coal power from being profitable to unprofitable. Coal's share of the UK's electricity generation fell from around 40% in 2012 to less than 1% in 2020. The UK's power sector decarbonisation over the period 2010-2019 was the fastest in the world, around eight times faster than the global average.[1]

Example 2: the world's fastest transition to electric vehicles

Norway has used a combination of taxes and subsidies to make electric vehicles cheaper to buy than the equivalent petrol cars. Along with other policies designed to make electric vehicles more attractive, this appears to have activated a tipping point in consumer preference. The result is the world's fastest transition to zero-emissions road transport. Norway achieved an electric vehicle share of car sales of over 50% as early as the year 2019, around twenty times higher than the global average, which was at that time 2-3%.[2]

Working towards a tipping point

Early models of the economics of climate change typically assumed that the more emissions a government aimed to cut, the more emissions-cutting would cost. The journey of decarbonisation was represented as climbing a hill that only ever became steeper. This would be the situation if no innovation or structural change ever took place.

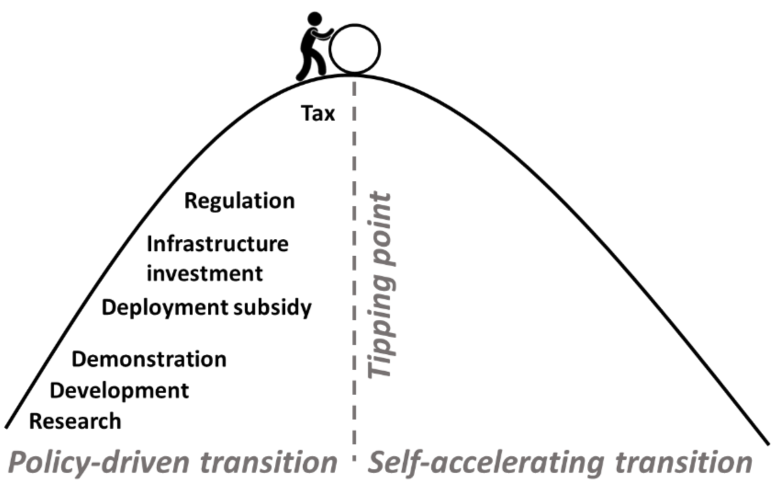

Figure 1: *The journey to and from a tipping point in a technology transition.*[3]

In reality, the presence of positive feedbacks between clean technology deployment, innovation, cost reduction, and demand mean that a low carbon transition can become *less* difficult or costly over time. In a very simplified way, the transition in each sector can be thought of as being like pushing a boulder over a hill.[3] The most effort is required at the beginning; it gradually becomes less difficult; and beyond a certain point, it begins to accelerate under its own momentum.

This visual metaphor is a reminder that just because a tipping point in the transition may exist, that does not mean it is accessible immediately. A series of policies is likely to be needed to bring a clean technology close to the point where with one more push, it can outcompete the fossil fuels.

---

[1] The carbon intensity of the UK power sector decreased by 8.9% per year between 2010 and 2019 (Drax: Electric Insights Quarterly, July–September 2020), while the global average power sector carbon intensity fell by 1.1% per year over the same period (International Energy Agency: Tracking Power 2021).

[2] For further details on these two examples, see Sharpe, S. and Lenton, T., 2021. 'Upward-scaling tipping cascades to meet climate goals: plausible grounds for hope.'

[3] Figure source: Sharpe, S., 2023. 'Five Times Faster: Rethinking the Science, Economics and Diplomacy of Climate Change', p.165.

Dynamic efficiency

The two examples above illustrate how, when a tipping point is crossed, a relatively small policy input can lead to a disproportionately large outcome. Such policies are dynamically efficient, or in other words, they get a lot of bang for their buck.

Traditionally, it has been suggested that an equal carbon price levied across the whole economy would be the most efficient way to achieve decarbonisation. The intention behind this recommendation is to maximise allocative efficiency[4], allowing emissions to be cut wherever that can be done most cheaply *at each moment in time*. But if the economy is changing, then there is no reason to expect this approach to achieve emissions reduction at least cost *over the course of time*. Instead, an equal carbon price across the whole economy is likely to be dynamically inefficient: if it happens to be at the right level to achieve structural change in one of the emitting sectors, it is likely to be higher than needed in some sectors (wasting resources), and too low to be effective in other sectors (wasting time).

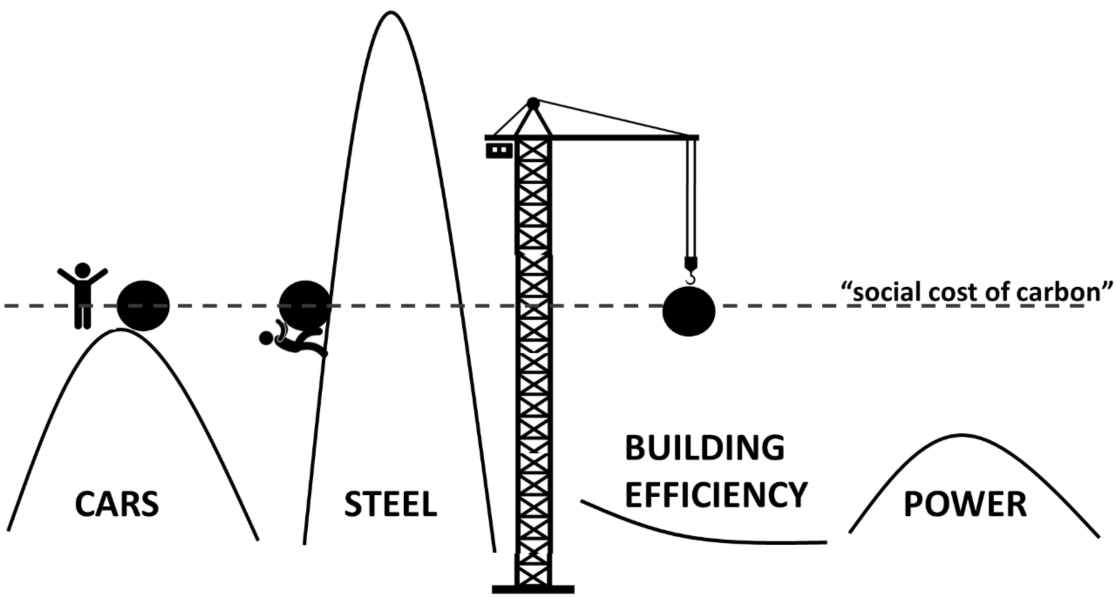

Figure 2: *The dynamic inefficiency of a uniform economy-wide carbon price.*[5]

A more dynamically efficient approach would be to set the carbon price (or clean technology subsidy) at a different level in each sector, targeted to make clean technologies cheaper or more profitable than fossil fuels.

It can be possible to achieve this effect without imposing high costs on consumers or public budgets. Tax-and-subsidy combinations can be designed to cross the cost-parity tipping point while being revenue neutral for the government. When clean technologies have a small share of the market, a small tax on the sale of each fossil fuelled product can fund a large subsidy on the purchase of each clean technology product. For example, a tax of $160 on the sale of each mid-range internal combustion engined car in

[4] Allocative efficiency is concerned with making the best use of a fixed set of economic resources at a moment in time. Dynamic efficiency is concerned with creating new resources (technologies) or structural change over the course of time. See Huerta de Soto, J., 2009., 'The theory of dynamic efficiency'.
[5] Sharpe, S., 2023. 'Five Times Faster: Rethinking the Science, Economics and Diplomacy of Climate Change', p.169.

Europe in 2023 could fund a subsidy of $1,600 on the purchase of each mid-range electric vehicle, achieving ownership cost-parity while maintaining revenue neutrality.[6]

Not just taxes and subsidies

A tax or subsidy may be the most obvious way to close the cost gap between a clean technology and a fossil fuel at a given moment in time. But regulatory policies can be highly effective at accelerating progress towards a cost-parity tipping point. A recent modelling study suggests that clean technology mandates may typically be substantially more effective in this regard than either subsidies or taxes, although there are important variations across countries, sectors, and stages of the transition.[7] This reflects the ability of mandates to force a rapid and large-scale reallocation of investment towards clean technologies, accelerating the processes of technology learning and cost reduction.

Not just costs

Old and new technologies compete with each other in more dimensions than cost alone: accessibility, convenience, and quality all tend to be important to consumers. Governments are more likely to succeed in crossing tipping points in consumer preference if they adopt holistic packages of policies that address all these dimensions. For example, Norway's government gave electric vehicles an advantage over petrol cars in terms of convenience by allowing them to use bus lanes and access free parking.

Profitability and growth prospects matter to manufacturers and investors. In sectors such as steel, cement, chemicals, maritime shipping, and long-haul aviation, clean technologies appear unlikely to become cheaper than fossil fuels within the foreseeable future, and highly-competitive international markets make it risky for companies to be first-movers in the transition. In these cases, the most important goal for policy may be to cross a tipping point in industry expectations, by creating conditions such that the new technology is perceived as less risky than the old.

Tipping cascades and super-leverage points

A 'tipping cascade' is where the crossing of one tipping point increases the likelihood of activating another, which in turn increases the chances of crossing another.

The participation of all countries in the global economy makes geographical tipping cascades highly likely. When first-mover countries pass a clean technology tipping point, their additional deployment and investment help bring down the technology's cost, bringing forward the tipping point in other countries.

Connections between the greenhouse-gas emitting sectors, particularly through shared technologies, mean that tipping cascades across sectors are also possible. For example, passing the tipping point in road transport increases deployment of batteries, bringing down their costs, and helping to make renewable power balanced with batteries cheaper than coal or gas. Cheaper clean power supports the decarbonisation of heating, transport, and industry.

In dynamic systems, cause and effect are usually disproportionate. Sometimes a large amount of effort can be expended without having much effect. A leverage point is a place where a small intervention can

[6] Lam, A. et al, 'Activating EV tipping points in China, India, Europe and the US', in Barbrook-Johnson, P. et al, 2023., 'New economic models of energy innovation and transition: addressing new questions and providing better answers', pp.88-111.
[7] Nijsse, F. et al, 2024., 'A positive tipping cascade in power, transport and heating'.

achieve a large effect. In each of the emitting sectors, a leverage point can be thought of as any action or policy that has a relatively low cost or difficulty but a relatively high impact on accelerating the transition.

A super-leverage point is an action that has relatively low cost or difficulty, and a relatively high chance of catalysing a tipping cascade. This has been defined as an action that is not only high leverage within its own sector, but that is also likely to have a significant positive impact on the pace of the transition in at least one of the other major greenhouse gas-emitting sectors.[8] Super-leverage points could be a useful focus for climate change diplomacy, since they are more likely to be activated if countries align their actions, and because they offer the potential to bring forward rapid and large-scale change in the global economy.

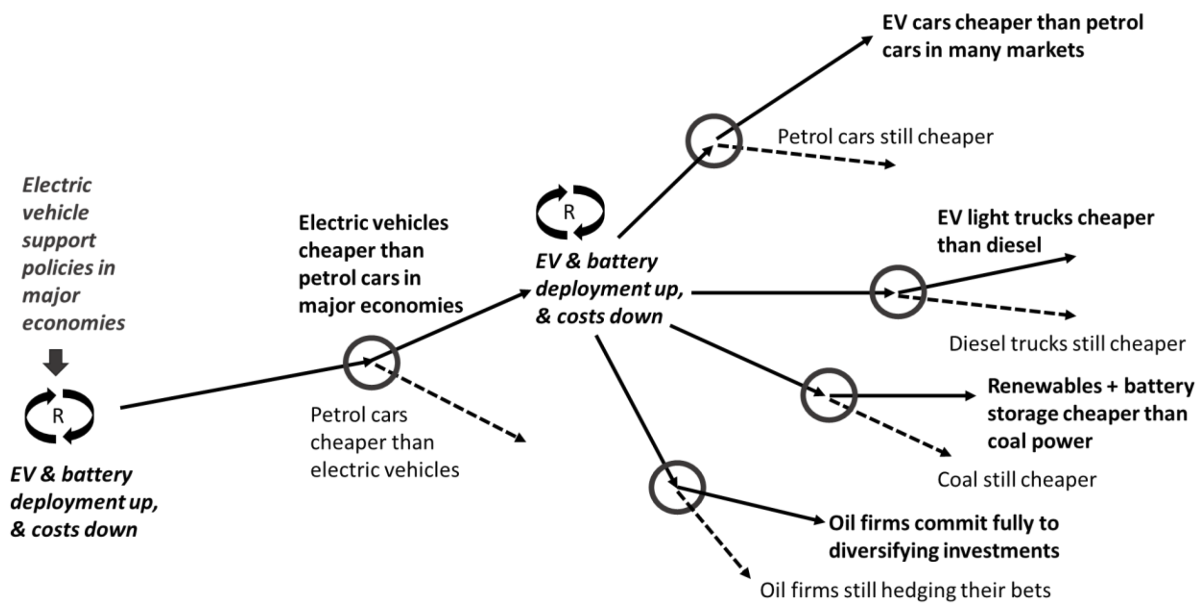

Figure 3: *A tipping cascade that starts with cars.*[9]

[8] Meldrum, M. et al, 2023., 'The Breakthrough Effect: How to trigger a cascade of tipping points to accelerate the net zero transition'.
[9] Sharpe, S., 2023. 'Five Times Faster: Rethinking the Science, Economics and Diplomacy of Climate Change', p.285.

Sources of further information

Our publication 'Five case studies to accelerate the low carbon transition' (Murphy, M. and Sharpe, S., 2024) contains brief notes and charts showing the potential to cross tipping points in the transitions to electric vehicles, solar power and energy storage, green hydrogen, heat pumps, and alternative proteins, drawing on a range of sources.

The academic paper 'Upward scaling tipping cascades to meet climate goals: plausible grounds for hope' (Sharpe, S. and Lenton, T., 2021) provides more detail on the two tipping point case studies mentioned above (UK power sector and Norway road transport), and outlines the basis for an understanding of tipping cascades.

The policy report 'The Breakthrough Effect: How to trigger a cascade of tipping points to accelerate the net zero transition' (Meldrum, M. et al, 2023) analyses how close tipping points may be in a range of sectors, and which actions could bring them closer. It also considers the linkages between sectors, and identifies three potential candidates for super-leverage points: zero emission vehicle mandates; green ammonia mandates in fertiliser production; and public procurement of alternative proteins.

Our new policy brief 'A positive tipping cascade in power, transport and heating' (Nijsse, F., et al, 2024) uses a simulating model to compare the relative effect of policies within and across sectors, providing a first quantitative analysis of the potential for a tipping cascade.

The World Bank report 'Within Reach: Navigating the Political Economy of Decarbonisation' puts tipping points and tipping cascades within the broader context of addressing the political economy challenges of the transition.

A range of materials on tipping points in the climate and economic systems has been published by researchers from 26 countries collaborating in the Global Tipping Points initiative.

The academic paper 'Operationalising positive tipping points towards global sustainability' (Lenton, T., et al, 2022) provides a framework and theoretical background for thinking about different types of tipping points, and how they can be activated.