7 PUBLIC GOODS AND ZERO MARGINAL COSTS

The polluter-pays principle applies because markets do a very poor job on their own in tackling pollution, but it is not sufficient, nor is it a strictly stand-alone problem. Pollution goes through systems. The car pollutes as it drives down the motorway, the coal pollutes as the electricity generated from it goes through the electricity system and the sewage goes through the rivers. All go through the natural systems, directly or indirectly.

These systems will not be well provided without public support. All have their own market failures. Most of them are in part or in whole public goods and natural monopolies. All of them have high fixed and sunk capital costs and low variable costs. For many, the variable costs (the marginal costs) are close to or at zero. There is little or no extra cost for producing an extra unit of output. This is the zero marginal cost problem and all systems need to be designed, supported, maintained and enhanced with this in mind.

Zero marginal cost is nothing new, but is becoming much more pervasive across the economy. It is at the heart of decarbonisation: nuclear and wind and solar are all near-zero marginal cost technologies. The wind and sunshine are free, and the costs of nuclear fuel are trivial compared with the capital costs of building a new nuclear power station. In all these cases, it is the high initial capital investment that dominates the economics, and once built the running costs are relatively small. More generally, digital technologies share this characteristic, and as more and more of the economy becomes digitalised, with Big Data and AI and in due course probably quantum computing, zero marginal costs are going to become the norm. This is an economic revolution in the making.

Zero marginal cost will define the cost structures of the sustainable economy. There will still be some marginal costs of pollution which require pollution charges, but the maintenance of the systems and their enhancement will need to be funded and financed on the basis of their overwhelmingly fixed capital costs. That presents a whole series of new challenges.

Public Goods

Public goods mean something very precise in economics and it is distinct and different from the public interest. There are many things that are in the public interest but which are not public goods, whereas the provision of public goods is typically in the public interest. Conflating the two sometime suits lobbyists and vested interests. Farming lobbyists, for example, try to reinterpret the new agricultural policy of 'public money for public goods' as meriting subsidies for anything in the public interest, and then conflate the public interest with the interests of farmers. Again, lobbyists obstruct the path to the sustainable economy, in this case erroneously claiming that food, a private market good which is in the public interest to produce, is a public good. Definitions matter if lobbying and capture are to be resisted.

Recall the discussion of the Coase approach to pollution, and his focus on property rights. These are at the centre of the incentive problems in respect of public goods too. Technically, a public good is one which is *non-rival* and *non-excludable*, contrasted with a private good, which is *rival* and *excludable*, and contrasts with an externality, which is *rival* but *non-excludable*. Public goods (and externalities) are a problem of defective property rights. Non-rivalry means that if you consume a good, so can I and everyone else, and at no extra cost (i.e. zero marginal cost), both now and in the future. The classic example is broadcasting: if you watch a film, so can everyone else without harming the quality of your experience. The only way a private business would produce this is if it could exclude you, unless you pay, for example by claiming a copyright enforceable through the courts and controlling your access to a platform to watch it on. Subscription allows all

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the subscribers to watch or listen at the same time, so Netflix, Spotify and the BBC licence fee do not price each viewing and listening even though they do exclude the non-subscribers. Contrast this with food: it is excludable and rival. If you eat it, I can't; and you and I can be excluded.

The problem with even this broadcasting example of creating excludability to the general service is that it excludes. The optimal amount of the good to produce is that which satisfies *all* the demands, whether or not everyone can pay the subscription or licence fee. Some people will place a very high value on watching and listening. Others less so. But each gets a bit of benefit, and if the aggregate of all these benefits can be delivered without changing the costs of delivery, then price should be equal to zero, the zero marginal cost, for the optimal economic benefit, which happens to be the maximum economic benefit because it costs nothing to deliver to each extra person.[1] Put simply, for the system public goods with zero marginal cost, no one should be excluded and the price should be close to zero, as it is for example in a number of free-to-use services. Where these are primary assets as part of the requirements for the citizens' capabilities to participate in the economy and society, there is a coincidence between the economically efficient outcome and maximising the citizens' capabilities.

These circumstances of zero marginal costs for additional users of the system or service arise in industries with lots of capital fixed and sunk costs, and increasing returns to scale: the average costs per unit fall with each extra unit of output. It is for this reason that public goods tend to natural oligopolies or even pure natural monopolies. Competition can actually be bad: for if there are competing capital structures in place, the average cost goes up. One water and sewerage system, one electricity grid and one motorway system are much more efficient than two or more competing systems.[2] Think of the duplication costs of multiple overlapping fibre networks and electric car charging networks which are currently being encouraged in many countries, compared

[1] This is the Samuelson formulation. P.A. Samuelson (1947), *Foundations of Economic Analysis*, Cambridge, MA: Harvard University Press. Formally, Pareto optimality is achieved when the sum of the marginal benefits equals the marginal cost, which is zero, rather than where the marginal benefits equal the marginal cost.

[2] The case of multiple fibre networks turns on whether the cost of additional cable is so cheap as to render these duplication inefficiencies sufficiently small relative to the gains from competition.

with the costs of concentrating on a single integrated fibre and car charging network. For renewable natural capital, there is and can be only one ecosystem.

Modern examples include Amazon, Google and Apple. Putting more stuff, digital or physical, through these platforms does not cost extra, just as putting an extra parcel on a postal delivery van which is making the journey anyway does not add any extra marginal costs. Ideas and knowledge are the ultimate public goods, with open-ended increasing returns to scale in their diffusion and applications.[3] Trust, the key feature of social capital, tends to display similar characteristics. A generally trust-rich society benefits all, even those criminals who free-ride upon it. Man-made network systems, natural systems and human and social capital all have these non-rival characteristics.

Zero marginal cost does not however mean that the provision of these system public goods is without costs. Quite the contrary. It is just that they are fixed. Someone has to pay, and this is where the funding question becomes central to their provision. If customers are not charged for use, there has to be some other basis for recovering the costs. Average and marginal costs are not the same thing. Marginal costs are those costs that are incurred by adding an extra unit of output, *given* the system. Average costs are those that average out the total costs, and hence in the systems where fixed costs dominate, the average cost equals these fixed costs, divided by the number of units of output.

Where there are some elements of variable costs, these can be separated out. *Access to the system* or platform (at zero marginal cost) should be priced at zero, but some *uses of the system* have positive costs, and these might be priced accordingly. For example, in electricity, this could be divided into a use of system charge (the fixed element, sometimes called the 'standing charge') and a use charge for energy transmitted through the system networks which will have marginal costs if it is generated from, for example, gas, but not if it is generated from nuclear, solar or wind, which are all technologies with near-zero marginal costs. As, if and when nuclear, solar and wind, all with

[3] Romer argues that it is these increasing returns to scale that lead to economic growth, and offset the Marxian view that the rate of profit must fall as scale economies from physical capital are exhausted. See P.M. Romer (1987), 'Growth Based on Increasing Returns to Specialization', *American Economic Review*, 77(2), 56–62. See also C.I. Jones (2019), 'Paul Romer: Ideas, Nonrivalry, and Endogenous Growth', *Scandinavian Journal of Economics*, 121(3), 859–83.

near-zero marginal costs, increasingly dominate the generation of electricity, so both generation and networks together drive the marginal price to zero, the electricity industry morphs into a capacity system, rather than a commodity market.[4] Since you either are or are not a customer of the system as a whole, you cannot switch. The result is a de facto monopoly, with the important consequence that who pays what contribution to the fixed costs can take account of social justice considerations because no one can escape paying. It is switching between suppliers that inhibits cross-subsidies to poorer customers.

Viewing public goods through the zero marginal cost lens is very different from the perspective of the public interest. It is also distinct from arguing that there are social and other benefits. It may be in the public interest to provide the social benefits of a free healthcare system to all, free of charge, but many areas of healthcare have considerable marginal costs, not least because of the labour involved in operations, treatments and consultations. Each hospital patient adds extra individual costs. These may be provided free of charge because it is widely agreed that, as a matter of social justice, access to these services should depend upon need, not ability to pay. Making the price zero when the marginal cost is not creates problems of excess demand: if healthcare is free at the point of demand, but not zero marginal cost, some form of rationing will typically be required. Queues are the way this is manifest in the UK.

It is important to sort out those bits of the sustainable economy that do and those that don't have zero marginal costs. Some aspects of healthcare do also have public goods characteristics. Examples include vaccination and immunisation, where if the population is fully vaccinated, then herd immunity is created, and all benefit from the reduced risk of infection. It is true that there is the (marginal) cost of each vaccination, but the benefits accrue to all for free, including the unvaccinated.

The ultimate public good is renewable natural capital. Nature provides at zero marginal cost its great bounty. It is not only non-rival and non-excludable now, but potentially forever. Privatisation of nature creates barriers to access for citizens, and private interests should never be allowed to determine the future of natural assets and in particular their ability to reproduce and stay renewable. Campaigns

4 See Helm, 'Cost of Energy Review'.

for access to the countryside reflect its public good, and controls over the use (or abuse) of peatlands, moorland and the seas are necessary to prevent harm. Protected areas should be just that: open to citizens now and in the future. What all this tells us is that a purely private market economy cannot meet the requirements of the sustainable economy.

Digitalisation and More Zero Marginal Costs

This gap between private and public will get bigger. Over time, there is likely to be a significant further erosion of marginal costs across the twentieth-century economy we have inherited and which was designed around marginal costs for a range of activities, for two reasons: first, as in the wind, solar and nuclear examples, high marginal cost production may be replaced by low marginal cost production; and, second, because digitalisation is a zero marginal cost driver, changing the very nature of production.

The electricity case illustrates a wider point. The twentieth-century great economic and population expansions were driven by fossil fuels, primarily coal and oil and then nuclear and gas. These all display variable costs, making spot wholesale energy markets impact on the whole economy. It is why, for example, despite an increasing amount of electricity coming from near-zero marginal cost renewables, the price of electricity followed the gas price shock in 2021 through to 2022 and beyond. This is because the gas power stations are the ones we rely upon at the margin to ensure there is enough supply to meet total electricity demand. Gas is the marginal fuel, with marginal costs. But all the rest (nuclear, wind and solar) have no marginal costs, and hence make a windfall profit at citizens' expense when the price of gas shoots up.

As more and more of the economy is digitalised, two overlapping things happen: labour is replaced by capital; and information technologies push and broaden technologies towards zero marginal costs. Consider a couple of examples. Online shopping is an automated process. A virtual shop sets up an IT system, supporting apps and websites. Algorithms do the ordering and accounting, not only fulfilling orders at close to zero marginal cost, but increasingly matching goods and services to people through advertising based on Big Data scraped from multiple past individual decisions and choices. A physical shop has heating, lighting and insurance, and it has shop assistants to deal with individual customers and their payments. The virtual shops and service providers have some remaining positive marginal costs primarily in the messy business of dealing with customers, and it is not surprising that major efforts have gone into replacing the option to call and speak to a human with AI and related chatbot services. It is all about driving out the residual marginal costs. Many customers of multiple products, including those of energy, water and transport utilities, have, as a result, been dealing with chatbots, not people.

A further example is provided by agriculture. Traditionally, farmers worked the land, and gradually farm workers have been replaced by machines. In the UK, cheaper EU labour has been deployed at scale to pick the crops and do other more menial tasks in abattoirs, particularly since the expansion of the EU to include Eastern European countries from 2004 onwards. The shock of BREXIT and the anti-European immigration policies have driven up the cost of labour. (There is always a wage that someone will accept for these tasks; it is just that it turns out to be a lot higher for UK workers than that paid to Eastern Europeans.) The result has been to speed up the digitalisation of farm work, increase the use of robots and add these to the gathering of data-rich mapping and granular digital detail of soils, crops and so on. Farming has always been a fixed-cost business: land is the key factor input. Digitalisation changes the ratio of fixed to variable costs further, with the marginal costs edging down. Even the fertilisers may tend towards lower marginal costs if they are made using zero marginal cost sources of electricity. The marginal costs – the farm workers – are squeezed out.

What these examples illustrate is a major change in the underlying technologies and, in turn, a significant change in the importance of public goods in the sustainable economy. As the new digital technologies proliferate, as everything is gradually digitalised, as the key assets become data, manipulated by AI, as fossil fuels are replaced with near-zero marginal cost nuclear, wind and solar, so the balance of the economy changes, and with this comes a radical shift in production and production costs, and hence in the fundamentals of markets, market design and the role of prices. These two examples give an insight into what is to come. Digitalisation will transform almost all economic activity. The coming of Big Data and AI on the back of the internet will make every sector of the economy have closer to zero marginal costs. The very nature of work changes, as it, too, becomes the application of fixed human capital to an ever-greater sphere of activities. Manual labour, the essence of marginal cost activity, will retreat further. In a fully digital world, it is reduced to a rump of personal services. Even here, it is surprising how much can be done by robots.

The scale of these changes will be made all the greater by new technologies to handle the mass of data. Quantum computing goes beyond digitalisation, utilising the space between the 0 and 1 of conventional computing. It is several orders of magnitude faster and capable of handling vastly more data.[5] The information technology revolution may have only just started.

What this means is that public goods in the sustainable economy of the next generation will move from a series of important cases to the mainstream, and the focus of the economy will be on their provision and the problems of incentivising their creation, investment and maintenance when the optimal (marginal) price is close to zero. This changes the game from just the simple correction of variable pollution charges discussed in the last chapter, to one where the provision of public goods is ever more important, and necessary for the limitation of pollution. Carbon has a marginal cost (howbeit small). The energy systems increasingly will not.

Why Markets Fail to Deliver

This big structural change towards more and more zero marginal cost production of goods and services raises the importance of the incentives, or rather the lack of incentives, for private businesses to produce them. It is here that the monopoly dimension comes in.

If digital technologies tend towards continuingly greater and greater returns to scale, and if the marginal costs are always as a consequence below the falling average costs, marginal cost pricing will result in losses. Where the marginal cost is zero, marginal cost pricing yields no revenue at all. Why, then, would businesses produce these sorts of public goods? How could they possibly recover their costs and make profits?

One answer notable in the broadcasting case, and the digital platforms, is to sell something else. Big Tech and broadcasters take

[5] On the potential of quantum computing, see www.imf.org/en/Publications/fandd/issues/2021/09/quantum-computings-possibilitiesand-perils-deodoro.

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your data, a by-product of your use of the service. The data is a positive externality you produce; it has a value for other companies who want to exploit the data about your choices to sell you and others something else.[6] Advertising-funded services are rife across the media. You produce your data free of charge to them, at zero marginal cost, and the Big Tech and media companies commoditise it and sell it on at a positive price. The bigger the audience of users, the more valuable the data is in aggregate, and hence scale not only shapes the costs of the platforms themselves, but also the value of the data.

This model tells us that there is an alternative. You could own your data and sell it, thereby capturing the profits from doing so. Behind the quite separate arguments about privacy lies a serious economic issue. To ensure you cannot do this (own your own data and sell it), you are asked to 'consent' to cookies and the site visited can then use your data, free of charge. In return, you get the public good, the network, for free, howbeit the one that produces the greatest by-product value to the provider.

Suppose one day governments legislate to make you the proud owner of your data, and thereby give you the property rights. What could Big Tech do? There are several answers, most of which are common to the other mainstream networks. Big Tech could create a monopoly and impose a user charge. If you want to use the service, even though you are zero marginal cost to the platforms, you have to pay. The monopoly could be protected by all sorts of barriers to entry to prevent others entering the market and bidding down the price towards the marginal cost. It becomes a market in capacity, in the systems and assets, not the marginal use of the system.

When new technologies come along with these network and system properties, there is typically a 'land grab'. Businesses scramble to gain as much market share as possible, hoping to end up with enough market power to impose high enough capacity charges to recover their costs. The great railway boom in the late 1840s is the classic example, and now there is the great land grab in rolling out fibre and car charging networks. Once they can charge you a user charge, the public good becomes a club good. You can be excluded from what is still a non-rival service, and interoperability barriers limit your ability to switch.

[6] When nature provides you with the sight of a kingfisher, you capture the image with a camera, and then the photo can be shared and even commoditised.

Winning market power is the prize, but the temptation to exploit a monopoly once created is typically so great as to lead inevitably to government intervention. The systems of the sustainable economy cannot be left in the hands of unregulated private monopolies. With no competitors to check pricing, the incumbent has an incentive to both ramp up the prices and enjoy what Hicks called 'the quiet life'.[7] Profits are maximised by higher prices and lower outputs. Why bother with capital maintenance, why invest in updating systems, when there is nowhere else for their customers to go? Why bother to innovate? Indeed, why not squeeze out potential entrants and rivals to protect existing assets and prevent new technologies rendering them stranded? Even if the profits are very high, any competitor entrant knows that the incumbent could retaliate by lowering its price and since it has a large market share, this is a very credible threat.

The result is suboptimal and there are lots of historical examples where it becomes seriously suboptimal. Why? Because the marginal cost is zero and hence demand that could be satisfied at no extra cost is not being met as the price is pushed up by the monopolist; and because the impact of lower-quality networks and less intervention is felt throughout the economy.

It is not just that there will be an economic loss from the poorer quality itself, but also that the resulting service failures from a poor network are asymmetric in their impacts. If the electricity networks are of excess capacity and hence have greater resilience to shocks, someone has to absorb the extra costs of the extra capacity margin; and it can be spread over the whole population of users. But if these are of poor quality, poorly maintained and underinvested, resultant power cuts have much larger impacts on all. In a context of uncertainty, it pays not only to have too much rather than too little capacity, but higher quality too. This asymmetry is felt on motorways with the costs of traffic jams, and it can be a huge factor in water. A failure of water systems stops much economic activity, whether it comes from failures to provide sufficient capacity in flood defences or failure to over-size water treatment works and water storage facilities.

When it comes to renewable natural capital, it is much better to be comfortably above the thresholds from which the assets can

[7] J.R. Hicks (1935), 'Annual Survey of Economic Theory: The Theory of Monopoly', *Econometrica*, 3, 1–20.

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reproduce and sustain their populations, than just below. The safe limits give resilience and avoid the risks of the renewables natural capital becoming non-renewable. From the perspective of the sustainable economy, the precautionary principle points to the need to regulate the quality and quantity of the core systems, to have excess rather than deficient supply.

An example that will most likely come to dominate these considerations in the physical networks supporting sustainable economy is the resilience of cyber networks, and in turn their reliance on resilient electricity supplies. The systems are now intimately intertwined. No electricity means no internet and no internet provision can mean no electricity. The costs of a major communications network failure are asymmetrically so much larger than the costs of over-provision. Just a short-term interruption in the payments systems can cause panic and bring much activity to a halt. That is why a cyber-attack is central to any offensive hostile military action. Taking down the electricity system is such a serious threat that in consequence many more businesses are investing in their own stand-alone electricity generation, even if the costs are much higher than reliance on the nationwide system.

The desirability of the resilience that having excess supplies of public goods brings further disincentivises businesses from providing them. Excess supply capacity is an additional pure public good, separable from the public good itself. It is designed to deliver resilience in the face of possible future shocks. If these shocks are not amenable to probabilistic calculation, then in the sustainable economy the level of this provision is a matter for the state. At the level of the planet, it makes little sense to consider these margins for the climate and biodiversity as a matter of cost–benefit analysis. Resilience is, as noted, particularly relevant to the safe limits above the thresholds for renewable natural capital.

In theory, a business could invest in these sorts of excess supply services, but they are unlikely to be sufficient, because the business can capture only some of the costs unless regulation forces someone to pay the full additional costs. If the benefits from over-capacity in fibre, electricity, water and transport are all at zero marginal costs, the classic public goods problem remains.

At the national level, whichever way you look at it, the monopoly route looks the most attractive for the private sector. It represents

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the best bet to get the fixed and sunk costs back. It is perhaps no accident that as the digital technologies develop, so too has the concentration of markets, helped by the digitalisation of the financial markets that in turn assist in the processes of mergers and acquisitions which help to create and reinforce these monopolies.[8]

The monopoly question arises in both the private and the public sector. Recall that it is generally less efficient to have competing providers of public goods. Monopoly may throw up problems, but competition could raise costs. There are essentially two solutions to the monopoly problem: designate monopolies and regulate them; or nationalise them.

In theory, the nationalised model shortcuts the choice of output, investment and cost-recovery mechanisms. The state can choose the output and prices without having to engage in the regulatory games that the private monopolists might play, and without the asymmetries of information that come from separating principals (the state) from agents (the private monopolies). But in practice, there are countervailing inefficiencies on the public sector side. Investment may be constrained by public finances, there may be political lobbying over the location of investments, and the principal–agent problems do not go away. The public sector can choose the balance between customer charges and tax funding, and has the option of providing the services free of charge, but it does then have to consider the impacts on the overall national budgets.[9] Either way, the monopolies will need regulating, a task we will return to.

The Coordination Problem in Systems and Infrastructures

The public goods elements considered so far comprise the production of the good or the service and their regulation, and the excess capacity margins to create and sustain resilience. The sustainable economy needs both. To these, there is a third element: coordination of the systems and infrastructures.

[8] The evidence of recent increasing concentration and associated market power is to be found in T. Phillipon (2019), *The Great Reversal: How America Gave Up on Free Markets*, Cambridge, MA: Harvard University Press.

[9] The Labour Party proposal to make broadband free of charge is an interesting case-study. See Labour Party (2019), 'It's Time for Real Change, Labour Party Manifesto 2019', www.labour.org.

Coordination is something markets are supposed to be good at. Through prices and markets, supply and demand are brought into equilibrium and goods and services are allocated accordingly. But when it comes to the main system networks, the coordination requires that the prices are right *in each system*, so that they mesh together into the sustainable economy. The electricity networks need to be built in tune with the development of digitalisation, and all the networks need to take account of the common data and communications infrastructure that increasingly supports, and is gradually dominating, all the other networks.

A moment's reflection on the zero marginal cost and the monopoly issues discussed above tells us that network coordination is unlikely to be optimally provided by private markets. Imagine a new business called 'National Coordination plc'. How would it go about its tasks? Who would pay and how would the free-rider incentives be overcome? It is most likely that coordination would be underprovided and ad hoc in its provision, as is witnessed in most countries.

A better way of thinking about coordination is to ask what the objectives are and what the aspects of each system that depend upon the others are. The UK's National Infrastructure Strategy makes a big play of the importance of resilience (as do the parallel plans in the EU and the US), but does not define how much of what sort of resilience is required, who is to decide how much and how it is to be paid for.[10] Resilience gets discussed in the silos of each system, with each system's regulator. Who simulates the impact on all the systems of a series of shocks that might happen? Suppose there is a cyber-attack on the electricity grid? How is this taken into account by the water sector and the water regulator? Suppose there is a heatwave or a drought? Or a pandemic? Suppose critical upstream natural capital is damaged by land clearance? How are the resulting flooding risks to be taken into account?

These examples illustrate a central point: the sustainable state needs a systems plan, and this is a role for the state not the private monopolies. The plan needs to be supported by an institutional structure. Someone has to be in charge. It can't be simply left to Austrian

[10] HM Treasury (2020), 'National Infrastructure Strategy: Fairer, Faster, Greener', November, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938539/NIS_Report_Web_Accessible.pdf.

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economics-style competition. In chapter 9, it is proposed that this is a role for a system operator with a system plan on the basis of system regulation.

A plan has to prioritise and focus on the primary public goods. Some public goods are more important than others, and the sustainable economy will be one that ensures that the main ones are delivered before worrying about the minor ones. Which ones really matter?

The answer is framed in terms of the assets that are required for citizens and businesses to flourish, and the ones through which much of the economy flows. We can try to work out some core principles to distinguish between them, but a more pragmatic approach starts with those that are definitely inside the boundary, before moving to the outer rings. To achieve the provision of just these, and their capital maintenance, would be a major first step.

They include the primary or core assets identified in the capabilities and citizens' approach set out in chapter 2, supporting the capitals identified in chapter 4. For citizens to flourish, they need energy, water, transport and communications, and they need renewable natural capital. They need human capital and social capital. They also need health and education assets, though not all of these are public goods. These are the primary assets. No citizen and no business can thrive without them.

That is the easy bit. The next question is harder: how much of each public good is required? We could resort to principles and sophisticated technical arguments, but as we have already seen cost–benefit analysis will not sort this out (because they are systems rather than discrete projects) and there are no *practical* economic tools for working out optimal public goods and optimal systems that provide them, other than saying that they should be large enough to incorporate all the demands and be resilient against shocks, subject to the overall resources available.

A pragmatic approach is the best place to start. On energy, it is a system capable of providing each citizen with the capacity that makes system access possible and a resilience that limits the chances of an interruption. It would have been helpful to have built in some resilience to Russia choking off gas supplies to Europe. The affordability crisis in 2022 demonstrated just how big the asymmetry between a resilient energy system and an inadequate one is. Many of the citizens will not be able to pay, and hence funding will have to be a mix of customer and taxpayer charges. On communications, a broadband network with system access is needed so that all citizens can access the basic services in the economy, including banking and education for children.[11] Resilience in the event of a Chinese invasion of Taiwan to interruption in the supply of chips would be a good idea, as well as to the supply of critical minerals from China. On water, clean drinking water and a sewerage system that prevents river water quality falling below a set of minimum standards and addresses storm overflows are essential. Resilience to droughts, flood and storms in the face of climate change is needed. On transport, a road system which facilitates the charging of electric cars and has a low probability of serious congestion, and a rail system which facilitates at least city access (instead of cars) and a supporting bus network are also essential.

In order to provide these systems, there needs to be coordination between them. All of them require a set of assets, and since these core services are likely to be needed for the rest of the century at least, they should be treated as assets-in-perpetuity, as described in chapters 4 and 5. All of them will need capital maintenance to ensure that the services they provide do not deteriorate, and as the bundle of system public goods changes with technological progress, they will need enhancements. All should go into the national balance sheet. All should use the same accounting basis.[12]

The most difficult part of defining the primary public goods and the assets required to deliver them is renewable natural capital, what nature gives us for free at zero marginal cost and which it can carry on delivering for free at zero marginal cost forever. What climate would be best? How much biodiversity is optimal?

Tempting though it might be to try to answer these questions, it is neither theoretically nor practically possible to do so. Nor is it necessary. With the renewable natural capital, we are where we are. As noted, it is not feasible to try to work out whether the concentration of carbon in the atmosphere prior to the Industrial Revolution was optimal. Those who lived through the very cold conditions of the

[11] During the Covid-19 pandemic lockdowns, when children were taught online, it turned out that many were excluded for lack of broadband access.

[12] An example of what happens when different accounting rules are used between gas and electricity networks. Electricity was historical cost; gas used current costs and this affected the location of new gas power stations. See D. Helm (2003), *Energy, the State and the Market: British Energy Policy since 1979*, Oxford: Oxford University Press.

seventeenth century would probably have taken a very different view. Similarly, we noted that, given that we do not even have a good and practical definition of biodiversity, it is impractical to try to work out even the optimal number of species. The reason is obvious: the natural assets all depend on their supporting systems, and defining optimal rainforests or optimal soils is not amenable to analysis unless first the optimal condition of all the other ecosystems is determined. The numerous economics articles and books on optimal public goods are of limited practical relevance.[13]

Given how radically the provision of these public goods would be compared with the status quo, the scale of the challenges to make the economy sustainable is obviously considerable. Public goods are not in a good place now. The provision of these systems of core assets requires a step change from what is currently happening. The renewable natural capital is not being maintained (it is going backwards), the electricity system and the transport charging systems lag the net zero requirements and the mobile, broadband and future networks for the digital economy are only now being created. Drinking water quality is mostly holding up, but the rivers and the sewerage side is grossly inadequate, and water supplies are jeopardised by housebuilding, high consumption and climate change. The global gap between what is needed just to hold the line and what is happening is huge. The academic question of what the optimal public goods systems would look like is just that – academic.

Paying for Public Goods

Given the scale of the challenge, how should public goods be paid for? In theory, if the marginal cost is zero, the price should be zero at the point of use. This means that the revenues required to remunerate the core assets and to pay for the capital maintenance must come as a system charge from some combination of current customers and current taxpayers and future customers and future taxpayers. Pay-as-you-go places the costs of these systems on the current generation. Pay-when-delivered pushes the enhancement costs onto future users.

The public goods problem is, at heart, a problem of the lack of property rights, the non-rivalry and the non-excludability we met

[13] C. Jones (2005), 'The Optimal Provision of Goods', chapter 10 in C. Jones (ed.), *Applied Welfare Economics*, Oxford: Oxford University Press.

earlier. We can either try to rectify the failures in the property rights, or the state can step in. In both cases, someone has to pay, and the only option which allows all and anyone to use the systems is one in which there is no *access* charge, and hence no access barriers, and no *user* charges. This is a neat approach: it is economically efficient and it separates out the provision from the revenue-raising. The revenue to cover system costs becomes in the very general sense a taxation question. The non-marginal costs can be a tax on all users on an ability-to-pay basis; a local tax in the case of municipalities and the application of this taxation classification to water and sewerage; or from direct taxation. Having social tariffs for poorer citizens allows for everyone to have access to these systems, and hence provide the capabilities to choose how to live their lives.

Yet this solution of zero access and use charges, and a general capacity charge, is almost never applied. The mainstream approach is to create a property right, and demand that users purchase some sort of licence to access the good or service. There are explicit or implicit licences for road users, for broadcasting, and there are even requirements for access to all but the basic health services in most countries. You pay a licence or subscription fee – a fixed charge – to access broadband. Even planning and other services from local government often come with a fee. Almost all licences collect money. Indeed, that is their primary purpose.

The obvious question is why charge for licences. If the free provision of these services is economically efficient, why do we not pay more tax and then have more public services free of charge? The answer goes to the heart of the sustainable economy. Voters demand more public goods, but also lower taxes. They want to free-ride, and where governments resort to borrowing, pass the costs on to the next generation. It is a well-known incentives problem, to which all sorts of technical solutions have been proposed, all essentially trying to confront us with the cost implications of the public goods we demand. Since we are not prepared to vote for the taxes to pay for these public goods, the second best is to introduce user charges and create licences as property rights. Privatisation is part of this second-best approach, and it has accelerated this shift to user charges. The likely alternative is to have limited or even non-existent public goods. In this regard, it is noticeable that European countries tend to have more and better public goods provision and higher taxes, whereas the US has the opposite.

Rethinking the Provision of Public Goods

Piecemeal charging to meet the systems maintenance and investment requirements has become endemic as the nationalised industries have been disaggregated, dismantled and privatised across many countries since the 1980s. Piecemeal charging is often a consequence of the way competition has been introduced to undermine monopolies, unbundling has taken place, and the emphasis on customer choice has confused the distinction between choosing the services that go through the systems and the impossibility of aggregating individual choices to define 'optimal' systems. Statutory monopolies focused on the delivery of systems have been replaced by the gradual unpeeling of the monopoly activities.

Ironically, as this agenda has unfolded, the state has repeatedly had to step back into a monopoly role, nowhere so obviously as in the case of electricity generation, where, in the UK, it has come full circle back to a CEGB-style central planning role, and across Europe the concept of a central buyer (implicitly or explicitly the state) has re-emerged. The state is the contracting party again, and not the customers of electricity. In water, disconnection ceases to be a legal option if customers do not pay, and large-scale state subsidies of the railways and buses have come back to displace the ambition to make these services rely entirely on user charges. Museum charges have had to be abolished. The great experiment of privatisation, unbundling, liberalisation and user charges has not lived up to the expectations of its proponents, and it is in retreat almost everywhere, and most notably in the UK.

For natural capital, this privatisation agenda has not been a positive one, though much deterioration took place before Margaret Thatcher and Ronald Reagan came along. Natural capital public goods are almost everywhere neglected. That is, after all, why we have environmental crises. There is no evidence that privatisation is improving them.

If the taxpayers are to pay for more of the provision of public goods in the sustainable economy, then it matters which taxpayers make what contributions. If users are to pay fixed charges, then it matters which users make what contributions, given that most of the costs are for fixed capital. The issue of social justice cannot be disentangled from the question of citizens' access to these public goods. That is the subject of chapter 8.