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Healthcare as social infrastructure: productivity and the UK NHS during and after Covid-19

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Abstract

This paper discusses the implications of the demand surge experienced during the Covid-19 pandemic for the UK's rationed, largely free at the point of need, National Health Service (NHS).

It explores the impact of the past emphasis on cost efficiency of the service in the light of considering the health system as part of the national social infrastructure. An infrastructure perspective incorporating resilience and peak demand considerations sheds new light on the performance of the NHS and underlines the role of the health care system in human capital investment and economy-wide productivity.

Introduction

The Covid-19 pandemic placed all countries' health services under great strain as waves of illness led to more hospitalisations, but the UK's experience has been unique in two ways. One is that almost everyone relies on the directly government-funded National Health Service (NHS) for treatment (Majeed et al 2020). Just 10-12% of the population purchase private insurance, but often this is for supplemental cover. Most people get most of their core health services free at the point of need (exceptions include many routine dental and opticians' services and means- and need-tested prescription charges). Changes in demand are therefore managed largely through 'rationing' – that is, queues. This compares with the mixture of private and public provision and financing in other OECD countries (Schreyer & Mas 2018).

The second difference is that, compared to other OECD countries, there were particularly large declines in measured health output in the UK even as the number of Covid-19 patients surged. Differences in system structures and statistical methodologies explain part of the contrast with countries such as Germany or Italy (see Schreyer, this volume); but another part of the explanation is that the UK system was operating so close to capacity that the number of non-Covid-19 treatments declined very sharply. Even Accident & Emergency visits declined sharply, more than halving from 2 million in England in January 2020 to under 920,000 in April 2020 and not regaining their pre-pandemic level until May 2021.[1] Large declines were seen across the range of NHS activities. The backlog of treatments remains high (in late 2021), with a waiting list for elective treatments at a record 5.72 million in late 2021 (up from 3.9 million in March 2020), and a sharp increase in the proportion of those waiting more than the target 18 weeks for their treatment.

Even setting aside methodological issues relating to the aggregate statistics, the drop in non-Covid-19 output would have been large because the NHS entered the pandemic with

[1] Data at : https://www.england.nhs.uk/statistics/statistical-work-areas/ae-waiting-times-and-activity/

no spare capacity. The context for the NHS was a severe financial squeeze, the consequence of a decade of austerity budgets. Total current healthcare expenditure in 2018 was £214.4bn, and both total and per capita measures have risen in real and nominal terms every year between 2014 and 2018. The NHS England budget was £148.8bn in 2019/20, increasing to £201.7 billion in 2020/21, which included £50bn for Covid-19-response.[2] Health expenditure broadly remained a broadly constant share of GDP at 10.0% from 2011 to 2019 (jumping to 12.8% in 2020), up from 6.9% in 1997. However, real terms annual growth in spending has been substantially lower since 2010 compared with all earlier periods of the NHS's existence (IFS 2018). Health care demand trends up over time as a share of the economy, with an income elasticity of demand greater than unity (Baumol 1967), a structural pattern reinforced by an ageing population. Spending increases have not kept pace with demand increases and so the NHS was struggling to cope practically and financially before March 2020 (PAC 2020; Propper, Stoye & Zaranko 2020).

Since the 1980s, the NHS, in England in particular, has been subject to a series of reforms generally aimed at increasing efficiency and introducing private sector management practices. This included the creation of an internal market within the NHS, which mandated a distinction between NHS organisations buying services and those providing the healthcare services. Criticism grew through the 1990s concerning the fragmentation of healthcare, however, as competition was in tension with the need for collaboration. For example, the desire to introduce digitization to improve services and productivity, requiring collaborative efforts to standardize and interoperate systems and data, has been hampered by the organisational changes. Subsequent reforms were thus nominally a reverse of the drive toward managerialism, but still maintained the internal markets, centralisation, and targets that were features of the previous reforms (Dalingwater, 2014). The 'multiple, overlapping, and often contradictory reforms' of the NHS in recent decades have been criticised for creating conflicting incentives for both collaboration

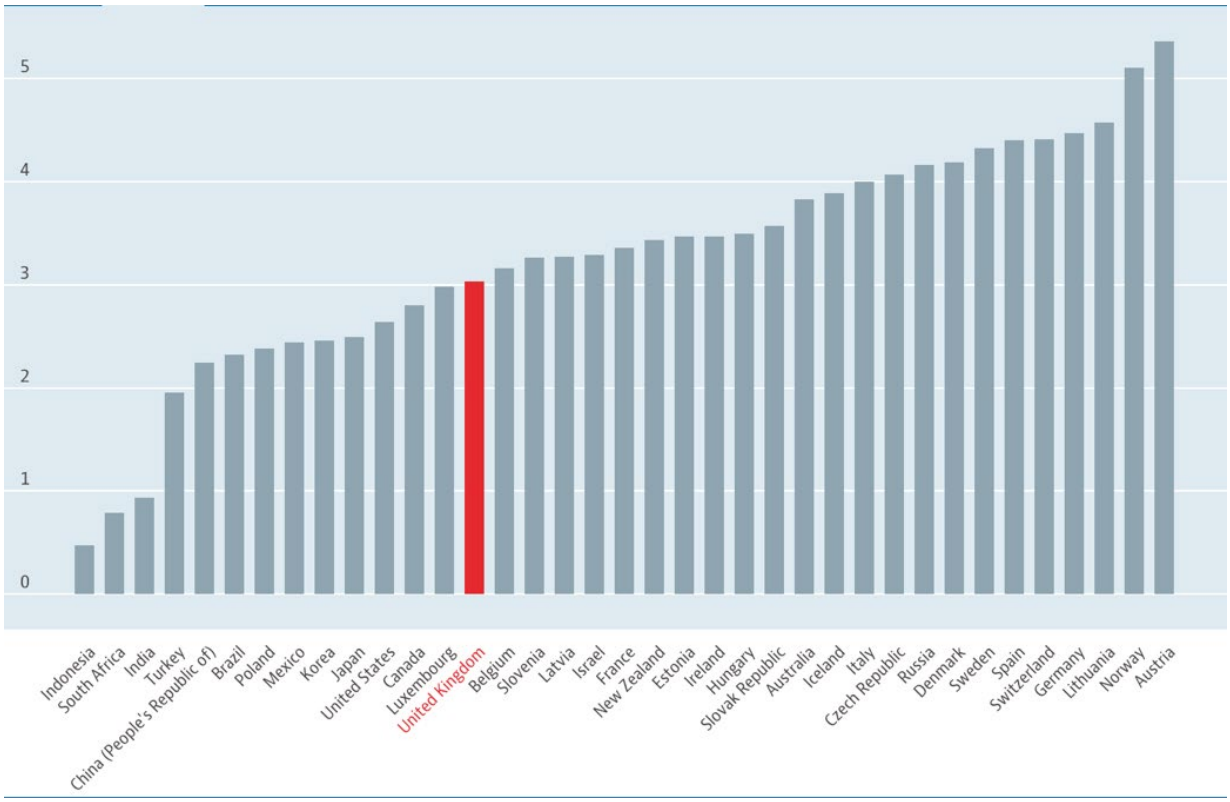
[2] The UK's devolved nations have separate budgets and the systems vary in important ways.

and competition between NHS organisations (Walshe et al, 2018). In 2021 another proposed reform has been published (DHSC 2021), creating a duty for the NHS and local authorities to co-operate to integrate care, and reducing bureaucracy, including by amending competition law to enable joint provision of services (Health Policy Insight 2021). The proposed changes will mark a significant move away from the prior emphasis on competition within the NHS, ending the internal market, and also indicate a shift toward centralisation of decision-making.

This frequent organisational change, along with structurally rising demand, formed the backdrop to continuing financial pressures and cost-cutting, especially after 2010. Based on pre-pandemic data up to February 2020, there was a projected shortfall of over 115,000 full time equivalent staff in England, expected to double over the next five years and more than treble in the next ten years (Shembavnekar, 2020). In the 2018 financial year, a year with a 2.3% increase in overall labour inputs to the NHS, FTE nursing staff numbers fell by 0.2% and GPs and GP staff numbers fell by 0.9% (ONS, 2020). The UK also has a relatively low rate of doctors relative to its population in the OECD, with 3 doctors per 1,000 people (Figure 1), below the OECD average of 3.5, and one of the lowest numbers of hospital beds per 1000 population (Figure 2) (OECD 2021). Although the UK does not rank so low on all indicators, the international comparisons show that on many core dimensions the UK health system has little spare capacity. As the pandemic hit in early 2020, the pressures manifested themselves as bed shortages and staff shortages. Although the NHS is the country's biggest employer, with 1.2 million FTE staff, there were around 90,000 vacancies by autumn 2021. The shortage of nurses was particularly acute, the number working in the NHS not having increased since 2010. In line with other countries, due to shift toward community treatments and day care treatments, the number of hospital beds has declined over time, but in the UK it more than halved, to 141,000, in the thirty years to 2020. According to the think tank the King's Fund, "In 2019/20, overnight general and acute bed occupancy averaged 90.2 per cent, and regularly exceeded 95 per cent in winter, well above the level many consider safe."

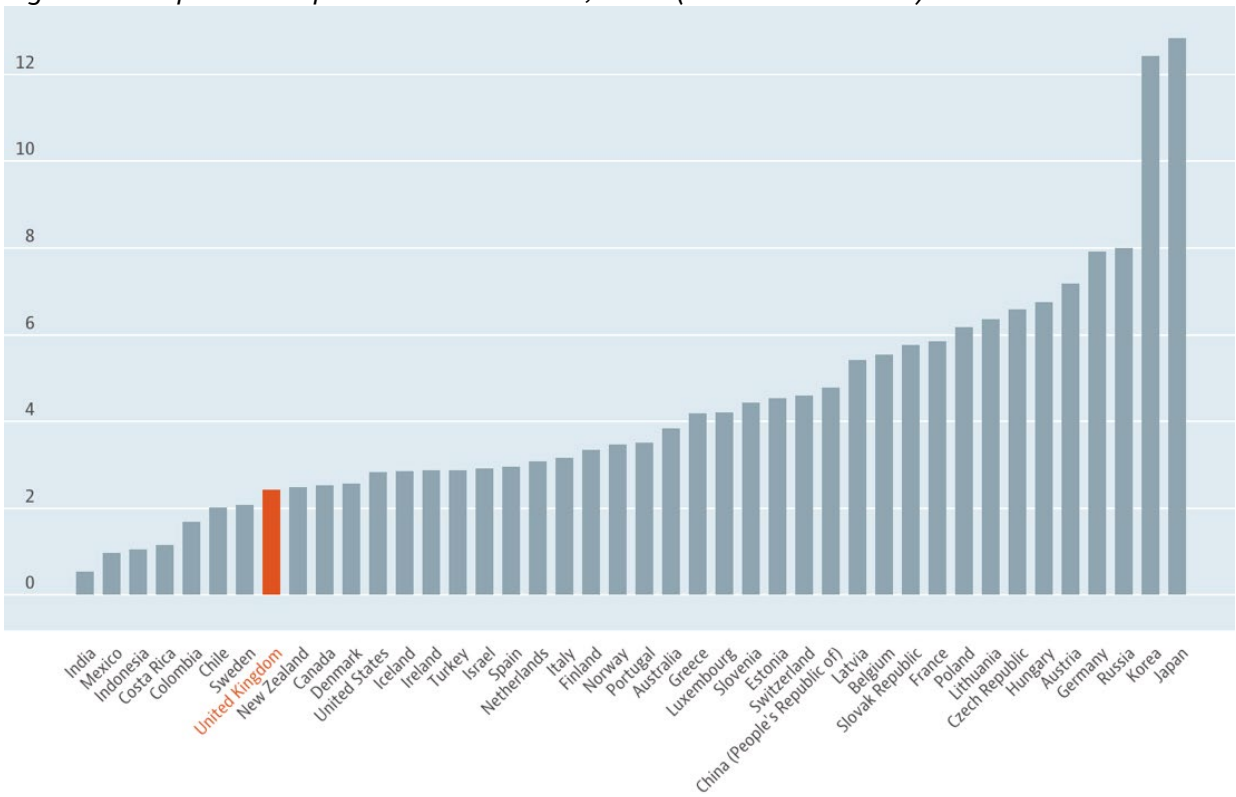
The pandemic thus exposed the vulnerability of the UK's NHS, given its under-funding relative to need and demand, and the absence of any spare capacity according to core indicators such as beds and medical staff.

Figure 1: Doctors per 1000 population (2020 or latest available)



Source: OECD (2021), Doctors (indicator). doi: 10.1787/4355e1ec-en (Accessed on 28 December 2021)

Figure 2: Hospital beds per 1000 inhabitants, 2020 (or latest available)



Source: OECD (2021), Hospital beds (indicator). doi: 10.1787/0191328e-en (Accessed on 28 December 2021)

Mendoza et al (2021) find that the closer a country's healthcare system was to 'saturation' or capacity limits (measured by ventilator and PPE availability and decline in non-Covid-19 treatments) at the start of 2020, the larger the recorded decline in 2020 GDP, even controlling for Covid-19 cases and mortality. The experience of the pandemic illuminates the need to consider the health system as social infrastructure, rather than as a service to be driven for maximum short-term efficiency. This perspective implies that provision should – like any part of the nation's infrastructure – take into account the need to deliver resilience, to accommodate demand peaks, and to consider its contribution to whole economy growth and productivity in determining investment levels. This chapter discusses these requirements in the context of the NHS. But first we turn to the question of the impact of the pandemic on the health service's own productivity.

Productivity of the NHS during and after the pandemic

Health expenditure and output form a substantial part of the economy (10% of UK GDP), and therefore the productivity of the health service is important in its own right. The long budgetary squeeze described above, relative to structural reasons for increasing demand and other resource pressures (such as demographic change, increasing expectations, and costs of medications, Stoye & Zaranko, 2019), has made productivity improvement within the NHS imperative. Official figures show that quality-adjusted productivity in UK public service healthcare indeed increased in most years from 1996/97 (Figure 3).

Figure 3: UK public service healthcare productivity (quality adjusted)

https://www.ons.gov.uk/economy/economicoutputandproductivity/publicservicesproductivity/articles/publicservicesproductivityestimateshealthcare/financialyearending2019; bars show annual growth, line shows cumulative level 1996=100.

The pandemic led to significant changes in practice, which are likely to have lasting implications for health service own-productivity, both negative and positive. In previous work (Coyle et al 2021) we identified several consequences for NHS hospital productivity:

- lasting changes in the use of physical space in hospitals (to create red, amber and green wards) and in staff practices (such as time and space for "donning and doffing" of PPE), in order to embed infectious disease control requirements. This will reduce effective capacity (in-patient and out-patient) in current facilities and given staff levels;
- reduced levels of non-Covid-19 treatments as long as the pandemic persists, with adverse consequences for output over time, given NHS capacity constraints;
- new activities including track and trace, and vaccination programmes, will add to output but compete for financial resource;
- rapid pandemic changes in the use of technology, both workplace productivity technology such as video-conferencing for staff, and technology for use with patients, such as video or telephone consultations – will persist; and
- changes in the organisation of services and in governance structures, giving the NHS greater operational flexibility and agility – have helped productivity but may be liable to reverse over time as 'normality' replaces crisis management.

Digital technology is the focus of hopes for productivity improvements. Just as its use spread rapidly in hospitals in 2002, similarly in primary care the NHS has moved to a 'total triage' model of care enabled by online, video and telephone consultations (Bakhai 2020), along with tech-enabled remote monitoring (also known as 'virtual wards') to support people with Covid-19 oximetry (Inada-Kim and Donnelly 2020). Adoption is widely expected to improve productivity and help cope with staff shortages, and it is being encouraged by NHS England.[3] However, there has been little evaluation of the impact on health outcomes. What's more, the record of introducing digital technology in the NHS has been mixed. There are two separate agencies dedicated to incorporating digital technology into health and social care. They are NHS Digital, founded in 2016, focussed on delivery support, and NHSX, founded in 2019, which focuses on strategic change. Both have been involved in aiding the Covid-19 pandemic response in terms of

[3] https://www.england.nhs.uk/wp-content/uploads/2020/01/online-consultations-implementation-toolkit-v1.1-updated.pdf

technologies such as remote monitoring, video conferencing, and 111 coronavirus services; easing the regulatory burden of data compliance governance; and delivering the NHS Covid-19 app (Lovell 2020). The current minister for health has accepted the recommendation of a recent independent report to rationalize and integrate these different digital health bodies (DHSC 2021b).

When it comes to potential productivity gains from digital in the NHS, organisational structures and regulatory frameworks seem more important than the use of technology per se (Freed et al 2018, Shigekawa et al 2018, Bronsoler et al 2021). While the benefits of some technologies, such as electronic health records, or the enforcement of greater inter-operability in software choices, seem straightforward, broad productivity gains will be linked to the ability to change organizational structure. The potential improvements include the flow of information around the system as a whole, which is crucial to determining both productivity (through internal co-ordination and process efficiency) and health outcomes (through joining up information about individuals and delivering co-ordinated services). The flow of information and the authority to take decisions – crucial to productivity and outcomes in a knowledge-based sector such as health – cannot be separated from questions of governance and organization.

There is a substantial literature on the link between organizational structure and the productivity benefits of digitalization in the private sector (eg Brynjolfsson, Rock & Syverson 2020; Brynjolfsson & Hitt 2000) and there is no reason to expect this to be different in public service healthcare – if anything, the reverse. In our previous work on NHS hospitals during the pandemic, we found that the removal of bureaucratic layers and the set-up of new taskforce structures softened the vertical and horizontal boundaries of services and hierarchies in hospitals, and enabled more coordination. Processes accelerated within hospitals and in their relationship with the external environment. Yet an acceleration of processes can put quality at jeopardy, as the example of the urgent need for equipment such as ventilators and PPE shows: accelerated bidding processes resulted in the procurement of lower quality products (NAO 2020). The

productivity with which the health service will operate in the future will largely depend on finding a balance between robust business-as-usual processes and flexible organisational structures.

The health system as social infrastructure

Although the productivity of the health service is important in its own right – for value for money reasons and because of its size as a sector of the economy – its importance extends to economic activity and productivity more broadly. The NHS is generally discussed in terms of its role as a service. The argument here is that it should be considered as part of the national infrastructure, specifically as social infrastructure. Some part of expenditure on health should therefore be considered as investment that will deliver subsequent capital services over time, not just as current expenditure on services, and moreover as a specific type of enabling investment underpinning productivity across the whole economy.

While there is no settled definition or description of social infrastructure, here it is taken to mean *long-lived assets in social sectors* (such as health, care, education, justice), where there are significant externalities, and hence whose provision is generally in large part organised, regulated and/or provided by the state (Coyle 2020). Following Fransen et al (2018), Corrado, Hulten & Sichel (2005) and Corrado, O'Mahony & Samek (2021), social infrastructure includes both *tangible assets* (such as hospital buildings, MRI scanners, ambulance fleets, research or diagnostic laboratories) and *intangible assets* (such as R&D, health software, management capabilities or other organisationally-embedded knowledge).

While infrastructure has traditionally been considered in terms of large-scale physical systems such as transport, communications or electricity networks, there is a growing emphasis on the similarly broad, underpinning role for social infrastructure. This too is sometimes considered in terms of physical assets and particularly the built environment

of publicly-accessible places where people can come together (eg Klinenberg 2018, Kelsey & Kenny 2021). This narrower definition has the advantage of drawing a relatively clear boundary for the purposes of analysis and measurement (not that either traditional or social infrastructure is well measured); yet both infrastructure types require a combination of physical and intangible investments in order to deliver capital services. There is strong evidence in general of the growing importance of intangible assets in the economy (eg Haskel & Westlake 2020) and hence the relevance of including them in the definition of infrastructure.

Expanding on Frischmann (2012), infrastructure assets are therefore defined here as having the following characteristics:

- They are non-rival (up to the scale where congestion occurs), and their marginal costs of supply are low relative to fixed costs;
- Demand for their use is driven by downstream activities that require them as inputs;
- They are generic - their capital services can be used as inputs into a wide range of other activities; and
- They have a legal and/or social obligation to provide universal and non-discriminatory access at a minimum service level.

The adjective 'social' is used to delineate parts of the economy's infrastructure typically involving significant public provision due to the wide scope of the externalities, non-rivalry and collective action challenges that characterise them, and having a strong emphasis on the need for universality at some minimum level of provision. It will be clear, though, that there is no sharp analytical boundary between traditional infrastructure such as the road network and social infrastructure such as the health system – underlining the case for including the health system as a part of the economic infrastructure.

The implications of regarding healthcare as social infrastructure are discussed in more detail in the following sections: the requirement for resilience in infrastructure; insights from the literature on managing peak load demands; and the role of health as social infrastructure in human capital and whole economy productivity growth.

Resilient infrastructure

The growing focus on economic resilience pre-dates the Covid-19 pandemic but is at the forefront of concerns given the experience of disruption since early 2020. It is a particularly important concept for infrastructure systems as these are enabling capital assets without which the economy cannot function. The UN's Sustainable Development Goals include a target for resilient infrastructure and the UK's National Infrastructure Commission's recent 'Anticipate, React, Recover' report presented a framework for testing resilience across the UK's energy, water, digital, road and rail infrastructures, to be implemented over the next few years (NIC 2020). While a Sector Resilience Plan is conducted every year for the health system in the UK, and health is one of 13 Critical National Infrastructure sectors,[4] the publicly available summaries focus on energy, transport, water and digital, with little comment on any sector. The latest available report, covering 2018, concluded with respect to health that the NHS and Public Health England, "have good levels of resilience and business continuity and an ability to divert resources from non-essential services in order for life-saving treatment to continue." Subsequent events suggest this was complacent. In addition to the sharp decline in non-Covid-19 treatments, described above, Public Health England has been abolished since the start of the pandemic. A House of Lords Committee recently concluded that the UK was and is exposed to a range of extreme risks for which government planning is inadequate (House of Lords 2021).

[4] Chemicals, Civil Nuclear, Communications, Defence, Emergency Services, Energy, Finance, Food, Government, Health, Space, Transport and Water

Resilience can be defined in several ways, ranging from simple definitions such as the, *"Ability to absorb and adapt in a changing environment"* (ISO 2018), to more evaluative definitions such as, *"The ability to understand and anticipate the risks – including new/emerging risks – threatening the critical functionality of the infrastructure, prepare for anticipated or unexpected disruptive events, optimally absorb/ withstand their impacts, respond and recover from them, and adapt/transform the infrastructure or its operation based on lessons learned,"* (Jovanović et al 2020). Resilience is also best thought of as a system property, rather than a feature of a single infrastructure component (Gallego-Lopez and Essex 2016). However, health investments tend to focus on large facilities such as hospitals (and on the treatment of acute illness) rather than on community facilities, preventive services, or public health (Fransen et al 2018).

The emphasis on cost efficiency in the NHS has discouraged investment in resilience, and encourages providers to opt for projects with higher short term net financial benefit. This short termism is compounded when calculations of the return to investment or the cost-benefit assessment is based on lifetimes that are shorter than the likely use-time of the asset, therefore giving limited incentive to invest in long-lasting structures (Gunthrie and Konaris 2012). Yet a recent OECD report concludes that, "Over the lifetime of infrastructure assets, the benefits of resilient investments are generally considered higher than the cost of inaction." (OECD 2021).

A National Infrastructure Commission report (2020) set out a framework for resilience in infrastructure involving:

- Publishing statutory resilience requirements every 5 years;
- Carrying out of regular and proportionate stress tests, overseen by regulators, and take action to address any vulnerabilities; and
- Development and maintenance of long term resilience strategies, with regulators ensuring regulation is consistent with resilience standards.

The House of Lords (2021) similarly called for greater transparency in the Government's sector resilience assessments. Publicly available standards have several benefits. First, the transparency allows for greater accountability. Secondly, transparency may consequently incentivise necessary investment. Finally, publicly available standards will reduce coordination costs elsewhere in the economy. For example, a private sector supplier can incorporate these standards directly into their investment plans without having to infer them. These recommendations are similar to the resilience analysis matrices proposed by Jovanović et al (2020). As these authors note, resilience in healthcare has been the subject of multiple 'lessons learned' reports after successive crises and they argue that most of the recommendations from these old reports still apply. There is limited added benefit of focusing on definition of resilience in health systems, so they instead recommend more focus on the emerging new risks, and more use of resilience indicators for better benchmarking and communication. Again, they see transparency as a key tool for encouraging investment in resilience.

As noted earlier, in the UK, within the NHS continuous cost-cutting has led to low staff and bed numbers relative to the OECD average. When capacity is reached, elective care must be postponed, and delaying treatment can increase the chances of a complication or the underlying condition getting worse, making the eventual treatment more costly (Ham 2021). This raises the question of how much investment in health infrastructure is required for system resilience, and to avoid counterproductive consequences when a crisis or demand surge occurs. In engineering, the concept of resilience is familiar, taking the form of sufficient redundancy (in construction or capacity) that the asset or system can continue to operate in the face of a shock or extreme events. Recent work on infrastructure resilience has coalesced around taking a *systemic* and *whole-life cycle* approach to evaluating infrastructure assets, ensuring *adequate maintenance* (including using new digital technologies to monitor their state), and implementing *effective governance and regulation* (OECD 2021a). However, social infrastructure in general, and health in particular, rarely feature in this literature.

Peak-load capacity planning

While the same principles of resilience certainly apply to the health system as social infrastructure, the literature on peak loads in the context of traditional infrastructure offers some additional insights into the question of how much redundancy is needed.

The combination of short-run fixed supply and variable, uncertain demand is a well-known problem in infrastructure sectors, with implications for pricing (where this applies), demand management (including queuing), and investment in (usually lumpy) capacity. For example, there is an extensive literature on the amount of capacity needed to meet demand peaks in the electricity sector, where the (current) inability to store electricity output at any scale makes the context similar to healthcare as a service that has to respond to current demand, whatever that might be. There are many software models available to model demand and supply in order that electricity providers can plan their trading needs or capacity expansion, although despite the maturity of the literature these do not incorporate the whole system – for example, omitting highly variable wind power generation and not taking account of skilled personnel constraints. As one recent survey summarizes the state of knowledge: "Electricity system planning and assessment is a dynamic iterative process with stochastic elements, which requires multiple inputs, constraints and decision paths to assess possible future changes and developments in the electricity system and market due to economic market forces and technological advancements, social demands and government policy," (Foley et al 2020).

The healthcare infrastructure system is even more complex. The idea of capacity planning has been developed in certain healthcare contexts, such as outpatient appointments (Aslani et al 2021), hospital departments (Larsson and Frederiksson 2019), and unplanned admissions in an NHS hospital (Moore 2003), while day-to-day operations management is a core need in complex healthcare environments. Logistics experts

indeed stepped in to help hospitals during the 2020 emergency.[5] However, these approaches tend to focus on short-term mitigation and management of risk rather than strategic planning. A strategic approach requires not only integration across different parts of the unit under analysis – for example, linking unplanned admissions with the consequences for waiting time targets in an individual hospital trust – but also across different parts of the NHS. For instance, Moore (2003) notes that the (still-prevailing) NHS plans to ring fence elective treatment centres and mobile units from the uncertainty associated with much healthcare delivery implies that non-elective services are also implicitly ring-fenced and thus unable to make use of other resources to manage their own demand peaks. A system perspective is needed, and he concludes that broader modelling techniques are required.

Part of the system approach required to evaluating longer term capacity needs will be to model the different inputs to health services as a whole, any of which might reach capacity limits. This includes staff as well as primary and secondary care capacity in terms of beds and equipment (and potentially social care too as discharging patients can often be held up by the absence of this provision). Healthcare provision should be regarded as a semi-fixed proportions production function in the short- to medium-term (Yfantopolous 1980, Ajao et al 2015). As noted, above staff shortages have been a major issue during the pandemic and are expected to continue. Training clinical staff takes many years (longer by far than the time needed to build the emergency Nightingale hospitals in 2020), and specialist skills are not transferable. While there was some retraining of other nurses and doctors to be able to work in ICUs in 2020, for example, many specialists were unable to work in the early part of the pandemic. Previously, workforce planning in the NHS largely occurred at the level of individual hospitals and practices, and had additionally not taken account of the impact of Brexit and changing immigration policy

[5] For example, https://www.ifm.eng.cam.ac.uk/news/ifm-receives-prestigious-royal-academy-of-engineering-award-for-covid-19-work/

on staff from overseas. In November 2021 the Government announced it would introduce a new approach to NHS workforce planning, without as yet any detail.[6]

The 2019 Long Term Plan for the NHS[7] committed to increasing staff numbers, particularly of nurses, but again with no figures. Nor does the document feature any strategic consideration of the capacity issues or quantitative modelling of demand and investment needs that would be at the heart of planning in any traditional infrastructure sector. And, as one recent evaluation of how the pandemic has changed long term need noted, there are inadequate data to monitor progress against what the plan does set out, and there is certainly inadequate resource to meet present and future need (Thorlby et al 2021). In particular, it noted: "For the NHS, the most glaring gap in government support is the continued omission of a fully funded, long-term plan for expanding and supporting the NHS workforce," (p58.) The Long Term Plan does not live up to its name.

Health, human capital and whole economy productivity

Unfortunately, there is an asymmetry in the measurement of publicly-provided social infrastructure and traditional infrastructure, and in the way infrastructure returns are assessed for example in cost-benefit exercises, which distorts the understanding of the importance of the healthcare system for the wider economy. First, capital expenditure by non-market producers is not fully included in the measurement of health output and hence GDP, in line with the international standards (only the cost of depreciation is included; see Jorgenson & Schreyer 2013). This is just one of the complexities of measuring health output, and comparing it across countries (see Schreyer & Mas, 2018, and Schreyer, this volume). In the present context, it means the decision framing for policy makers will be a comparison of spending choices where one is seen mainly as a cost, albeit essential, to be minimized, and the other as an investment offering a return, albeit requiring financing.

[6] https://www.gov.uk/government/news/major-reforms-to-nhs-workforce-planning-and-tech-agenda
[7] https://www.longtermplan.nhs.uk/online-version/

As regards the impact of social (rather than traditional) infrastructure, there is a paucity of empirical evidence, as van Ark (2021) points out. The positive relationship between infrastructure and scale or potential growth has been found to extend to legal infrastructure (Leaven & Woodruff 2007, Tsintzos and Plakandaras 2020). Agénor (2010) proposes several channels through which infrastructure can promote productivity and growth, including specifically the impact of health and education services on the quality of private inputs, affecting firms' choice of technologies, operational scale, and factor mix; but he too points out the research gap regarding social infrastructure.

The direct way health will affect growth is through its impact on the stock of human capital, as it has a direct effect on worker productivity (Bloom & Canning 2003). In an early paper, looking across countries for 1960-1990, Bloom et al (2001) included health and experience as well as education as measures of human capital, and found that good health had a large, positive and significant effect on aggregate output growth. A more recent study looking at very long term data found the same strong relationship (Sharma 2018). Using the example of education as an intangible social infrastructure, Corrado, O'Mahony & Samek (2021) find that incorporating UK education into the standard measurement framework implies a less severe slowdown than currently measured in UK total factor productivity. Their approach could be applied to expenditure on healthcare as a similar investment in intangible social infrastructure. It is not yet standard for health status to be incorporated in human capital stock measures, but this is changing. The World Bank has recently developed a new human capital index incorporating health metrics.[8] O'Mahony and Samek (2021) set out a framework to incorporate health status in the UK's human capital stock statistics, calculating for 2018 that the total would have been 12% higher if those people in poor health and been in good health (mainly due to greater workforce participation rather than differential earnings).

[8] https://www.worldbank.org/en/publication/human-capital

However, health (and education) as social infrastructure will have potentially large indirect effects on productivity and growth through their social spillovers. A general issue concerning infrastructure evaluation is that its social value exceeds that created by its direct consumption: most of the value will derive from the subsequent productive use (derived demand) of the service provided. What's more, its use will have potentially non-marginal consequences, involving spillovers that change economic conditions. An example in the domain of the transport network would be a new rail line creating a larger, thicker labour market in the locality, and consequent reallocation of labour to more productive activities. In the health context, the productivity spillovers derive from improvements in human capital (see below) and as these are locationally-specific, with a strong correlation between measures of health such as life expectancy and indicators of economic deprivation, local population health improvements can trigger positive productivity spirals in certain places due to increasing social returns to scale and threshold effects (Azariardis & Drazen 1990). In such cases, the directly measured return to the specific investment (a rail line, a new hospital) is an understatement of the total social return. To some extent this can be offset in cost-benefit exercises by taking account of 'wider benefits' but this is not standard practice, and not part of the analysis determining investment in health systems at all.

Given the time lags and complex contexts involved, it is difficult to evidence empirically the links between particular types of infrastructure investment and outcomes for aggregate productivity and growth, not least because of the simultaneity involved. There is certainly a positive correlation at the macro level even though specific projects often 'fail' (at least in financial terms) (Coyle 2022). A meta-analysis by Born & Ligthart (2014) confirms the existence of a positive relationship between public capital and growth. Again, there is scant evidence of this kind as regards the role of social infrastructure. Even so, expectations about the availability of public infrastructure will certainly affect private investment decisions and hence future growth paths. Depending on expectations, there can be multiple equilibrium outcomes, with higher growth paths requiring both sufficient aggregate demand and high-quality infrastructure (Daido & Tabata 2013); the

larger the scale of production, the greater the need for high quality infrastructure. Chakraborty & Dabla-Norris (2011) show that the quality of public capital services can have a large effect on aggregate productivity. Esfahani and Ramirez (2003) conclude from cross-country estimates that the contribution of infrastructure services to GDP is substantial and, in general, exceeds the cost of provision of those services. Frischmann (2012) sums up: "There is tremendous demand for public infrastructure and … infrastructure plays a critical role in economic development, but exactly why there is demand, how it manifests, how it should be measured, and how it contributes to human well-being are not well understood," (p19).

Conclusion

Tangible and intangible assets of the health system should be regarded as part of the public infrastructure, that is as enabling assets that produce inputs – human capital – used across the economy and generating social spillovers. In some of its official documentation, particularly its critical national infrastructure assessments, the UK government does treat the health system as such. However, the experience of the Covid-19 pandemic made clearer than ever the costs, in terms of lack of resilience and productivity losses, of running the NHS too close to capacity. The lens of good infrastructure planning, including resilience, system and whole life approaches, governance and transparency, should be applied to future plans for NHS expenditure.

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