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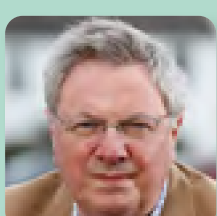

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THE SOFTWARIZATION OF REGULATED NETWORK INDUSTRIES AND ITS CONSEQUENCES FOR COSTS AND COMPETITION

By Martin Cave

Advances in data and digitalisation create substantial opportunities for cost savings and enhanced competition in many network industries subject to regulation. By softwarization to mean innovations which reduce the need for hardware assets; these can be not only code, but the use of any smart asset, algorithm or economic tool across the whole value chain. The scale of the potential effect on costs of softwarization is linked to the weight of digitizable activities in the typically 'fused' digital and physical processes which make up network industries. Two sectors are considered. In mobile communications, the scope for digitisation and the starting level of competition are high; in electricity, both are substantially lower. In each case, the potential financial and structural impacts of such innovation are quantitatively significant. The paper also notes regulatory issues which may arise when owners of hardware networks may seek to limit the access to market of their new software competitors.

01 INTRODUCTION

The argument of this paper is simple and straightforward. It is that there are immense opportunities associated with the use of data and digitalization to achieve a combination of significant cost savings and the enhancement of competition in network industries, such as energy and telecommunications. In particular, competitive pressure in different forms can be imposed on the network component of the value chain, in many cases hitherto seen as being impervious to it. And this benefit can be achieved from innovation either within that component or upstream and downstream in the value chain.

This new element in network industries can be called the softwarization of network functions. In caricature, when there is a need to a need to replace existing network assets or when demand for a sector's end product has risen, the only solution available has been a hardware one - replacing an old transmission line, or building a new one (the latter being a process in the energy sector which in some jurisdictions takes as long as a dozen years). However, data and digitalization introduce new "software" possibilities, by which I mean the presence not only of code, but of any relevant smart asset, algorithm or economic tool across the whole value chain which can "replace" hardware assets. This can be done relatively quickly, and in some cases at a cost an order of magnitude or more lower than the hardware alternative.

I illustrate these possibilities with two different examples. The first is mobile communications, where the traditional value chain (typically comprising a fiber fixed backhaul connection to a tower, which supports antennae giving access to a radio access network connecting the network's retail subscribers) relied on a local distribution technology which since its origins forty or so years ago has demonstrably been a natural oligopoly, rather than the then more generally observable natural monopoly in fixed communications. In fact, the number of mobile networks observable in advanced economies is now (and has for decades almost invariably been) either three or four, the outcome often depending on past merger control investigations, and probably including a fair amount of sharing of fixed assets.

In consequence softwarization of mobile does not introduce network competition where there was none before, but rather – in conjunction with a potentially game-changing new 5G technology - creates major new possibilities for competition, as described below, which have the potential to disrupt the industry's structure.

The second is the energy sector – where physical transmission and distribution networks are still bastions of natural monopoly. The recent focus in many countries on attaining net zero carbon emissions by 2050 implies a many-times-over increase in electricity demand – the generation and network hardware costs of supplying which would be enormous. But my definition of software includes anything from a demand reduction scheme which signs up a million households which allow their fridges to be switched off for an hour or so in the face of an expected increase in peak demand, or a time-of-day tariff which incentives householders to charge their electric vehicles ("EVs") overnight rather than in the evening, to carefully located battery storage which overcomes a bottleneck in a distribution network, or a real time "flexibility platform" which runs auctions in which a variety of firms can offer competing services which circumvent hardware capacity constraints. The multiplicity of options brings in many new potential providers to compete with the hardware monopolist.

In terms of the level of head-to-head competition in their pre-existing market structures, our two case studies lie pretty much at the opposite ends of the spectrum observable in sectors with local delivery networks. This is linked to a second broad underlying difference between them which arises from the nature and ease of the digitalization processes occurring within them. The communications sector was the first to be subject to a digital transformation, beginning in the 1980s. The same process for broadcasting started a little later. By now, all over the world, analogue communications exist mainly in small pockets and specialized uses.

Government digital strategies (not always fully implemented) for the whole economy or the public sector alone have appeared with increasing frequency in recent years. Consultancies have not only proffered advice on strategy but have prepared copious international league tables. For example, the Financial Times/Omdia Digital Economies index computes 16 digital economy measures for 39 countries for 2020-2024.[2] The measures comprise 2 for connectivity, 4 for devices or I0T, 2 for Enterprise ITspend, 6 for entertainment and 3 for payments.

The focus here on data transmission and communications is apparent and natural. However, whole economy digitalization requires the fusion of digital and physical processes. While data downloads and telephone calls require only the transport of bits, which may of course fulfil the aims of education or health, as well as of communication or entertainment, the provision of energy also requires such physical assets as gas pipes or electricity transmission networks, both of which may carry attendant risks to life and limb. Equally, the large-scale use of IoT based on a dense 5G network within an advanced manufacturing factory will involve physical processes, including major tangible capital assets, and other material inputs, at whatever geographical scale it is attempted. The degree of digital/physical fusion required in a sector's digital transformation has a big impact on what cost reductions and increases in competition can be achieved in it, and at what cost.[3]

2 https://www.ft.com/content/d6ebd098-3f81-4638-afba-b1a1a572163c.

3 As a further illustration of this point, compare the purely digital changes associated with development of ride-hailing platforms such as uber, with fusion of digital and physical processes associated with the use of driverless cars.

02

SOFTWARIZATION IN MOBILE TECHNOLOGY[4]

In mobile communications, these developments are inextricably connected with the development of 5G, which in some cases takes the form of a somewhat better version of 4G, often still using some 4G elements, but in another more expansive stand-alone version is capable of embodying much greater versatility and of delivering the speeds of 1 gigabit which (made universally available) are the target of digital strategies in several jurisdictions, including the EU.[5]

A. 5G Networks

5G is the first generation of networks to embed two key software features. The first is software defined networking (SDN). This transfers the functionality needed in the network such as switching and handover from hardware to software, enabling variation in services and functionality to be made more readily.

The second is network function virtualization ("NFV"). This involves implementing the functions of the communications infrastructure in software running on standard computing equipment, following the precedent of data centers, which went through a similar transformation. This reduces costs and simplifies the addition of new services. The framework for these developments has been standardized by bodies such as ETSI.

These two advances allow a single network to supply bespoke combinations of speed, latency, geographical coverage, and other attributes to meet their customers' varying needs. This is known as "network slicing." It also allows the provider of a digital education or transport service, for example, to buy connectivity at wholesale and bundle it with the rest of its service.

An early example of this is provided by Rakuten's 2020 5G network in Japan. A second is new U.S. Dish network in 2021.[6] According to The Economist the latter is "except for antennas and cables, mostly a cluster of code that runs on Amazon Web Services." This "cloudification" of networks brings new giant software firms into the game, competing in the same space as pre-existing hardware providers.
Finally, the above-noted Dish network adopts the practice of using different tiers of spectrum bands, known as versatile spectrum: "each band of the 5G spectrum will work together as best needed to provide more data capacity. By combining the bands, DISH Wireless ensures a better 5G network where all its spectrum works together towards a common goal."[7]

B. Changes in Competition

What else might happen in the marketplace? One possibility is wide-area coverage for niche applications. This may be needed to support a growing number of IoT applications with homogeneous geographical needs. Existing networks meeting enhanced mobile broadband needs and providers of niche services might be active here. Examples cited include smart metering, public safety networks and broadcasting.

A further example is the market for local coverage and capacity, meeting the needs of a group of contiguous end users, who may be a specified private interest group, such as a group of firms in an industrial park, a group of firms offering driverless vehicles, or individual members of a residential community.

In the limit, it could be a private network provided for a single firm. It is notable that AWS has announced a new managed service to help enterprises to set up and scale the new private 5G networks described below, and Ericsson has made an agreement with BT jointly to supply the same service in the UK.[8]

Spectrum regulators are increasingly preparing to make licenses available for such so-called verticals. In a recent German spectrum auction, the regulator reserved one quarter of available spectrum for such closed user groups, which can rent access for 10 years for €31,000 per square km. By mid-2021, 117 such licenses were approved. A less radical way of achieving the same end is to authorize or mandate localized spectrum sharing in appropriate bands.

Finally, many mobile operators have sold their masts to specialized companies, which now, particularly in the light of the above changes, have the capacity to integrate into network provision and become wholesale only operators.

In combination these changes have the potential to lead to a major shift in the structure of the mobile market.

4 For more details on this section, see M. Cave, "5G and the wider goals of digitalisation in the EU," in E Bohlin & F Cappelletti (eds), *Europe's Future Connected: Policies and Challenges for 5G and 6G Networks*, ELF 2022 available at https://liberalforum.eu/wp-content/uploads/2022/06/Europes-Future-Connected_ELF-Study_Techno-Politics_vol.2-2.pdf.

5 European Commission, *Europe's Digital Decade*, 2021, available at https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade.

6 https://godish.com/dish-spectrum-holdings-and-5g-plans/ (accessed Jan. 10 2022).

7 https://godish.com/dish-wireless-versatile-5g-spectrum/.

8 *Financial Times*, May 31, 2022.

03

SOFTWARIZATION IN THE ELECTRICITY SECTOR

As noted in the introduction, the electricity sector is far more capital-intensive and complicated than mobile communications and entails a much more thorough-going fusion of the digital and the physical. As a result, the developments I describe in this sector are much more diverse. I limit myself to describing two simple examples which illustrate my wide definition of softwarization set out above, and then note, under the more comprehensive rubric of flexibility (and flexibility platforms), the infinitely more varied and sophisticated set of measures which are currently under development. I also discuss one of the regulatory issues created by the emergence of this new form of competition to hardware.

A. A Simple Retail "Software" Illustration

Electricity must be consumed in the second it is produced (unless it is expensively stored – see below). Accordingly, the major hardware costs of generating capacity and networks have been dimensioned to meet the maximum load from business and domestic customers, which varies predictably by season, day of week and ambient weather conditions, generally peaking in early evening.

A wide class of demand-side reduction measures which pay customers on a more ad hoc basis to reduce consumption has been discussed and implemented for many years, in many variations and with respect to both business and domestic customers. But here we focus on a very simple means of reducing peak demand. This is time-of-day pricing, which encourages customers to switch to off-peak consumption times. This requires a meter which measures consumption in each 5, 10 or 30 minutes. Large business consumers have had this facility for many years, and many jurisdictions have dictated a universal roll-out of such smart meters to households.

The clearest opportunity for such time-shifting arises in connection with charging electric vehicles. Tariffs available overnight can be a small fraction of those at peak hours. Numerous trials over several years have demonstrated the large consumer response.[9] Customers can also install digital assistants which choose the optimal moment to charge vehicles or use other electrical equipment.

In some jurisdictions tariffs link the price charged directly to the spot price in the wholesale energy market. This subjects such customers to considerable risks. Thus when wholesale prices spiked dramatically in Texas in February 2021 as a result of very low temperatures, some customers were reported as having faced bills amounting to many thousands of dollars over a very short period.

However, such time-of-day pricing options may be most fully exploited by households which own EVs, have large premises and are digitally competent. Poorer and older households may end up continuing their previous consumption habits at now much elevated peak rates. This is a matter of concern to regulators which are charged with protecting such vulnerable customers.[10]

B. Wider Applications of Softwarization: Distributed Energy Resources and Flexibility Markets

The potential of digitalization ("smart energy") goes way beyond the above, and is driven by several factors. One is the increase in the role of weather-dependent (and hence intermittent) renewable sources of energy, which adds greatly to the complexity of balancing supply and demand. The second is the growing number of distributed energy resources ("DERs"). These are small-scale units of power generation that operate locally and are connected to a larger power grid at the distribution level. DERs include solar panels, small natural gas-fueled generators, electric vehicles, and controllable loads, such as electric water heaters. An important feature of a DER is that the energy it produces or stores is often consumed close to the source.

This permits a broader change in the supply-demand paradigm, from one in which large and controllable power stations were required to adapt supply to a given demand, to one on which demand has to be made more elastic and controllable. This generates a need for so-called flexibility markets which bring together a large variety of different generation, storage, and demand reduction technologies which to allow the supply/demand balance to be achieved in a new way. The EU's "clean energy packages" are designed to fulfil this function.[11] The UK is pursuing a similar plan.[12]

To facilitate flexibility markets, it may be necessary to create a platform, as a venue on which providers can make their offers available and buyers can signal their needs. Two types can be distinguished: peer-to-peer platforms - which facilitate energy trading between individual businesses or "prosumers," operating at local levels. And grid services platforms - those which provide a wide range of grid services, often involving greater network coordination and bringing together either large assets, or smaller assets that have been aggregated together to

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9 See for example the results of an early trial by Vector in New Zealand, at https://www.ena.org.nz/resources/publications/document/826.

10 For an analysis of how softwarization might affect regulation in this area, see Chris Decker, *Protecting consumers in digitized and multi-source energy systems,* available at https://www.tandfonline.com/doi/full/10.1080/15567249.2021.2012541.

11 See for example Energy Systems Catapult, *Towards a smarter and more flexible European energy system,* 2021, available at https://esc-production-2021.s3.eu-west-2.amazonaws.com/2021/10/Catapult-EU-FLEX-Report.pdf.

12 *Transitioning to a net zero energy system: smart system and flexibility plan 2021*, BEIS available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1003778/smart-systems-and-flexibility-plan-2021.pdf.

meet grid requirements. Regulators in many jurisdictions are encouraging the development of such platforms.[13]

C. Regulating Hardware/Software Competition in Electricity

The depth and coverage of electricity regulation exceed that of mobile regulation by many times. Transmission and distribution networks in private ownership, currently subject to very little competition, are almost invariably price-regulated, and usually very profitable. This may give them an incentive to expand their networks.

At present, in many European jurisdictions in particular, the so-called task of "systems operation" (coordinating the planning, management and real time operation of the electricity networks with the activities of generators and retailers) is allocated to the country's transmission and distribution operators.

As the competitive options described above grow, they may fall victim to self-preference on the part of the network owner charged with systems operation. It may prefer to earn the return allowed by the regulator on additional network assets than to procure competing alternatives. This concern has led to plans or proposals in Great Britain and elsewhere to structurally separate the two tasks at transmission level, following the example of independent systems operators in north America in particular.[14] As local flexibility markets multiply, the same may occur at distribution company level.

Whoever makes the above hardware/software choices over how to meet at lowest cost the changing demand for the product must, however, find a rationale for doing so. Pressure to achieve net zero will almost certainly increase demand for electricity in coming decades, as will the need to accommodate more renewable generation.

This is not an unprecedented investment choice problem. Consider the owners of a factory making mousetraps. When the number of mice is forecast to grow, they face a choice between a hardware solution (expand the factory, but by how much?) and a software solution (add a night shift to the existing production roster, which can be done quickly and is reversible). With some approximations to knowledge of the probability distribution of demand growth, the slope of the supply curve of software solutions, and the lead times for and degree of economies of scale associated with different hardware expansion options, there is probably a determinate solution to this problem. It might be the case that some of the software solutions are substantially cheaper than some equivalent hardware solution but are indefinitely replicable. It would be surprising if either of the two corner solutions ("hold the software solutions in reserve solely to deal with forecasting under-estimates" and "first use up all available software solutions") would be optimal.

04

EXTENSIONS AND CONCLUSIONS

This account has just scratched the surface of the possibilities created in network sectors by data and digitalization. As noted, these depend upon the combination of digital and physical activities. In the nature of things, the nature of this combination is likely to determine the degree to which the growth of softwarization makes a difference both to costs and to competition.

In mobile communications, each new network generation has a major effect on costs and quality of service. These benefits are closely associated with softwarization in the case of 5G, which will be followed by 6G with its much greater degree on sustainability. In the electricity sector, by contrast, the impact will be more limited. I am not aware of firm estimates of how far flexibility markets and other software tools will go to reduce costs. It is likely to be small fraction of total sector costs, but so large is the likely expansion in demand in a country like Great Britain, this might plausibly amount to annual savings of many billions by 2050.

The two sectors considered here stand at opposite ends of the spectrum in relation to the degree of head-to-head competition they can embody. We have noted above in mobile communications the scope for a proliferation of digital networks, whereas in energy competing software remedies sit within a framework which revolves around price-controlled hardware monopolies whom regulators may suspect to have an incentive to stifle software, if they control the single buyer of software services.

What are the general lessons here for network regulators?

- Softwarization is a set of innovations which can confer substantial benefits on the customers (businesses and households), whose interests regulators are usually duty-bound to protect.
- Within that customer group, there may however be some, especially those who are less digitally qualified and affluent, whose position may be worsened by the process.
- Regulators must be aware of the possibility that hardware networks whose market power is diminished by such developments may seek to impede entry by software competitors across the whole value chain.

13 See Ofgem*, Flexibility Platforms in Electricity Markets*, available at https://www.ofgem.gov.uk/sites/default/files/docs/2019/09/ofgem_fi_flexibility_platforms_in_electricity_markets.pdf.

14 BEIS and Ofgem, J*oint Statement on the Future Systems Operator*, 2022, available at https://www.gov.uk/government/consultations/proposals-for-a-future-system-operator-role/outcome/joint-statement-on-the-future-system-operator.

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