This report was commissioned by Qualcomm. All opinions expressed here are those of the authors, who are employees of Compass Lexecon. It is based upon a larger report, *The Economic Impact of Technology Standards*, available for download at http://www.compasslexecon.com/highlights/economic-impact-of-technology-standards/?year=2017. In the interests of space, we have not fully referenced all of the material used here but the longer report contains extensive references.
1.1 Many of the products we use in everyday life are only useful because they connect with other products. These connections can occur at many levels. Consider a smartphone. Obviously, it must be able to connect with other phones, smart or not, through compatibility with the wireless communications infrastructure. It must be able to make connections, through cables or wirelessly, with nearby IT equipment. It might need to be able to display images or play music that arrived over these connections in all sorts of formats. It downloads apps from a choice of many thousands, all of which are able to display images or text, play sounds and access other functions. Inside the case, things become no less complex, as equipment from countries all over the world works together. A smartphone is not a piece of technology, it is a nexus of many thousands of different technologies, all connected and compatible.

1.2 Technological compatibility raises important policy questions. Technological progress is the most important contributor to long-term economic growth, as well as driving social and environmental change. Yet control of key technologies creates concerns about concentrated economic and social power, particularly for technologies and platforms with which other products must interact. The rules governing these interactions will influence the success and development of firms, new technologies and the economy as a whole.

1.3 When technologies connect, there is usually some form of technological standard enabling this to happen: specifying what is required to connect, whether to a single connecting platform or in a network of multiple products. Of course, standards serve many purposes and not all are concerned with technical compatibility, although that will be our main focus here. Many industries are effectively defined by the presence of standards and the way in which these standards are established and governed can have profound consequences for how competitive and innovative those industries are.

1.4 Standards are not new. Since the nineteenth century, railway tracks have increasingly come to use the so-called ‘standard gauge’ initially established by George Stephenson. The advantages of a single standard for the industry and its consumers are obvious and there are no longer any competing contenders for the dominant standard, yet some alternative gauges persist.

1.5 The economics of many information technology industries strongly favour the emergence of a single standard. Such industries often have strong economies of scale and scope, as it costs next to nothing to provide information to more consumers. Network effects, in which users gain value from the presence of other users on the network, are often important too, whether through direct effects (the more people are on Facebook the more each subscriber benefits) or indirect (the more people use Windows, the more software developers will produce applications for Windows).

1.6 Standards help these industries achieve scale, giving users and suppliers the confidence to buy or make compatible products. However, researchers have also found that industries

---

1. Stephenson used the 4’8½” gauge for the Liverpool and Manchester railway in 1830, apparently basing it on existing tracks for mine-carts. Sadly, the story that the gauge itself reflects an ancient standard created by the ruts and axle widths in use on British roads, ultimately going back to the wheel base of a Roman chariot, is almost certainly a myth. The gauge is widely agreed to be inefficiently narrow, but the world is surely stuck with it by now.
making use of standards are more innovative and dynamic over the longer term. A study comparing productivity growth rates in industries reliant on standards to those that are not, found notably better performance in the ‘standard-reliant’ industries. This result held up even when comparing these standard-reliant industries (mostly in IT) with productivity growth in other semi-conductor based products that did not use standards, which might be expected to have benefitted from the same ‘Moore’s Law’ productivity growth from the underlying technology, as we illustrate in Figure 1 (Page 1).

1.7 Standards seem to do more than simply solve a co-ordination problem, they seem to lead to rapid innovation. We recently published a report exploring why.2 We conclude that the institutional framework for developing and updating standards is crucial: the ‘gatekeeper’ who defines and updates a standard possesses great power. The gatekeeper has technological power to determine the way in which the industry develops and also economic power to monopolise several levels of the supply chain.

Who is the gatekeeper?

1.8 What kind of organisation acts as the gatekeeper will depend on how standards are developed in the industry. There are three broad models.

a. Firstly, a standard might simply ‘emerge’, becoming a de facto standard for the industry. Typically, such a standard will be under the proprietary control of a single company. Operating systems (O/S) used on personal computers provide an example.

b. Secondly, standards can be sponsored by governments. Television broadcasting is an industry which has always relied on government-set standards over most of the world: from the initial ‘wars’ over colour TV standards, through to modern standards for digital broadcasting.

c. Finally, wireless telephony standards and many others are set through voluntary participation by experts from many different companies collaborating together in standard development organisations (SDOs3). In general the process allows for participation both by innovators (technology providers) and implementers (firms that will manufacture the resulting devices). Innovators normally receive license fees payable on ‘Fair, Reasonable and Non-Discriminatory’ (FRAND) terms for technology declared essential to implementation of the standard.

1.9 Our analysis, building on the work of others, shows that there are clear benefits to voluntary, collaborative standard-setting, resulting in better outcomes for consumers as well as faster innovation and economic growth. In our report, we describe how standards developed in three industries: mobile telephony, PC operating systems and TV broadcasting – and affected the way those industries themselves developed.

1.10 We find that the collaborative, voluntary standard development process in the mobile telephony industry has led to a more competitive market structure than in other industries, where standards have a single proprietary owner or are set by government. In the mobile phone supply chain, for example, there are many producers of telephone handsets, as we illustrate in Figure 2 above, and there are even more

---


3 Often referred to as ‘standard-setting organisations’; or SSOs, but we prefer the SDO terminology as a better descriptor of what these bodies actually do, as the process of developing a standard is a dynamic and interactive one.
competitors supplying their components and the software and applications that run on them.

1.11 Crucially, many firms also supply technology into the mobile communications standards themselves. With more innovators participating ‘upstream’, competing to provide the technology and then collaborating in the resulting standard, there are more independent sources of ideas, there can be more competition and there can be more specialisation than would otherwise be the case. For example, Neul, a small company with less than 200 employees founded in 2010, was a major contributor to ‘weightless’ standards. ‘Weightless’ is a set of open standards developed by a Special Interest Group comprising 1400 members including large firms, such as Qualcomm and Huawei.

1.12 The resulting technical progress has been astonishing. Download speeds illustrate the point, as we show below, but more fundamentally there are many more things that mobile telephones can do than before. The contribution of collaborators in research shows its effects not merely in faster performance but in disruptive and transformative technologies, which can come about because innovators of many different types can contribute ideas to the mobile telephony ecosystem.

1.13 In contrast, PC operating systems embody a standard for the apps-hardware interface that is usually under the proprietary control of a single company. The great majority of PCs continue to run Microsoft’s operating system, which can work with hardware and applications produced by multiple suppliers, but its development is under the control of a single company. The second player in the industry, Apple’s, system is still more closed: working with Apple hardware and exercising more control over the applications that run on its systems.

1.14 It would be wrong to think of the high share of Microsoft O/S on PCs as a problem. The near-universality of this standard provides great benefits, through network effects and economies of scale. Where there are no institutions setting standards, multiple standards might fight out a ‘standards war’ – which is competition in a sense, but it also misses out on efficiencies of a single standard and there is no guarantee that the best technology will win.

1.15 However, there are downsides to this proprietary control. Firstly, it is possible that the O/S itself would be better with a more collaborative approach. Studies of handheld computers have shown faster innovation when other companies can participate in development of the O/S itself. Secondly, the standard owner has economic power that enables it to monopolise other layers of the supply chain. Whether that power is used or not, the perception of its can make other firms reluctant to invest in connecting products, for fear that the standard owner might make a change rendering those products incompatible or even itself begin providing the functionality of those products within the O/S.

1.16 Alternatively, standards can be set by government. However, the history of government standard development – from TV broadcasting for example, or for that matter in the early days of mobile telephony, shows that competition and innovation can often be stifled. Since the 1960s, Europe has had two standards for analogue broadcasts of colour TV: PAL, which was originally German, and SECAM deliberately developed and promoted by the French state out of concerns to protect French TV set producers from their more efficient German

rivals. The resulting global map of standards reflects political allegiances more than any economic considerations, with countries historically within the sphere of influence of France and the USSR adopting SECAM while others adopted PAL or the US NTSC standard. Protectionist economic policies rarely succeed even in their own stated aims, and the result was more expensive TVs and eventually an uncompetitive industry.

1.17 Lest this story be assumed to belong to the bad old days of state intervention, the more recent adoption of digital TV standards in Latin America has followed a similar pattern. In 2006, Brazil adopted a Japanese standard as part of an agreement to produce sets to that standard, then sought to persuade other Latin American countries to adopt it, to promote its producer interests. Some other countries chose their standard for political reasons – Mexico choosing the US standard, Venezuela rejecting it, for example. None of this is likely to help create an innovative and competitive industry.

Markets for technology

1.18 Why do we see these differences? One reason is that voluntary, collaborative standard-setting allows for a diversity of firms working in R&D. The system makes it easier for many different innovators to contribute technology to a huge technological system (such as the mobile wireless network) and – crucially – be rewarded for it. Licensing of intellectual property rights creates what has been called a ‘market for technology’ in which firms buy and sell the rights to use innovations rather than products embodying them.

1.19 Of course, markets for technology can exist without SDOs. Many American inventors in the nineteenth century, including Thomas Edison and Charles Goodyear, relied mainly on others to commercialise their innovations through licensing. Effective legal protection of intellectual property rights is important for licensing to be possible. For example, semi-conductor designs only become clearly covered by IP protection in the US with the Semiconductor Chip Protection Act (1984). Only after that did self-standing ‘fabless’ companies emerge: specialised in design and without any manufacturing activity. Without this development, there would be many fewer firms researching in semi-conductors because of the economics of chip manufacture. The ‘fabs’ where semi-conductors are manufactured are huge, benefiting from large economies of scale. If every semi-conductor designer needed also to be integrated with a ‘fab’ there would be many fewer designers. However, because the market for technology it is possible to have a few giant firms in manufacturing, while preserving a diverse field of specialised R&D outfits.

1.20 The mobile phone industry demonstrates how licensing combined with collaborative standard-setting can lead to more diversity in R&D. An astonishing number of inventions are incorporated in each mobile standard. The top 40 companies contributing technology to each standard together held 2802 patents in 2G, 7088 patents in 3G and 10,476 patents in 4G. This increasing complexity has not, however, been accompanied by more concentrated ownership. Quite the reverse: the top five companies held 69 percent of inventions in the 2G standard, 58 percent of the 3G and just 48 percent of the 4G standard. Even the top 20 companies own only around 90 percent of the inventions in any of the generations, implying a very long tail of smaller contributors to the technology. In contrast, in TV broadcasting standards, the top five patent-holders hold between 83 percent and 98 percent of technologies in the standard, while obviously

---

5 Edison should have made more use of licensing than he did; his manufacturing efforts were less successful, as Henry Ford noted when describing him as “the world’s greatest inventor and the world’s worst businessman.”

---

Figure 4: Most of the growth in US R&D has come from expanding the pool of firms doing R&D, not from increased expenditure by the big R&D leaders

![Graph](source: Adapted by CL from Foster et al. (2016), Figure 3.)
in PC operating systems only Microsoft and Apple own technologies in Windows and O/S, respectively.

1.21 Small firms contributing significant R&D runs against traditional economic thinking, which saw R&D expenditure as being almost entirely carried out by larger industrial concerns. Economists have often regarded R&D – like advertising or the creation of brands – as a strategic tool by which larger firms keep smaller rivals out of their industry. Empirical studies have reliably found that higher R&D/sales ratios are associated with more concentrated industries – those dominated by larger firms. Indeed, this makes perfect sense if the only way to make money from an invention is to produce a product that incorporates it.

1.22 However, if successful innovation can be rewarded directly through licensing this link becomes weaker. To be sure, the majority of industrial R&D is still carried out in larger firms, but the trend has reversed. US National Science Foundation surveys find around 12% of R&D carried out in firms with less than 500 employees in the early 1990s and between 16 and 20% in recent years. It is becoming more viable to be a small R&D player and indeed to be a ‘pure-play’ researcher, as it was in the nineteenth century USA. Perhaps the assumption that R&D is usually conducted in an integrated R&D department in a large industrial firm should be seen as a twentieth-century historical aberration. Licensing is essential to this development. Standards can be still more effective in promoting R&D, because the smaller innovator does not need separately to demonstrate its ownership of the technology rights through bilateral negotiations.

1.23 The more firms there are engaged in R&D, the more independent solutions to problems will emerge. Furthermore, these firms can specialise. So innovation will be faster but there may be wider benefits as well. This market structure seems likely to reward individual inventors more than would a more concentrated industry. When technology markets are dominated by a few giants, an inventor might have very few alternative possible buyers for their innovation. If you have a suggestion for how to improve Microsoft Windows, you need to talk to Microsoft about it. However, with standardised technologies, there can be multiple implementers of an innovation, making it more likely that innovators will be rewarded for their creativity and hard work.

The importance of fair, reasonable, non-discriminatory and dependable outcomes

1.24 These impressive economic outcomes arise from many firms working together, through institutions that set the rules of the game: Standard Development Organisations. To understand the importance of the rules, consider a very simple arrangement with just one innovator (‘she’) developing technology and one implementer (‘he’) who can manufacture and sell devices. If the resulting product can be sold for more than enough to cover each of their investments, they should be able to strike a deal to work together, but whether they will be able to do this depends on the rules of the game.

1.25 The problem is one of timing and commitment. If the innovator invests time and money in the new technology and then seeks a deal with the implementer, her bargaining power may be weak. The implementer knows that the innovator’s costs are sunk— at that point, she will accept a deal giving her less than her investment costs because it is better than nothing. However, if the innovator fears this outcome in advance, most likely she will not invest. A similar problem arises if the implementer invests first, building a factory, or indeed if they both invest before attempting to negotiate a deal. If negotiations on licensing take place after investment, there is no reason to think the split will cover both parties’ investments.

1.26 It therefore makes sense, instead, to negotiate before investment has taken place. However, innovation is an uncertain business. It is by no means certain what value the two should put upon the finished product and it is very risky to commit to a particular number. One solution to this dilemma is for the two to merge together into a single integrated firm— it is precisely for this reason that we might expect to see industries dominated by vertically-integrated firms doing their own R&D and making devices that incorporate its results. As we have seen, however, this industry structure is far from ideal.

1.27 An alternative solution is therefore to agree the broad rules of how a licensing negotiation will be conducted in advance, without agreeing a specific number. This is why SDOs typically require innovators to commit to ‘Fair, reasonable and non-discriminatory’ licensing terms when innovators declare their inventions to be essential to implement a standard. All the participants in the SDO commit to this rule in order to provide one another with the certainty required to invest— the rule provides a commitment device, which is essential because after investment has taken place, each side would prefer a deal that does not reward the other’s investment, as we have seen.

1.28 Crucially, however, the rules-setting organisation must stick to the rule. There is nothing more likely to harm the incentives of innovators and implementers to invest than to change the rules for how license fees should be set after the participants have committed to investments. In a few cases, SDOs have indeed changed their rules and have seen a fall in participation by innovators as a result.

1.29 In 2015, in an attempt to address issues arising from the vagueness of FRAND commitments, the Institute of Electrical and Electronics Engineers (IEEE) amended its policy which required licensors to offer licences to all applicants, to forego their right to injunction except under limited circumstances; and also recommended a method of calculation of reasonable royalty rates. Katznelson (2016) examines rates of licensing Letters of Assurance at IEEE and finds a sharp (and statistically significant) reduction when changes to patent policy were brought in 2015. Not only did the rate of new LOAs fall, some patent holders actually declined to license under the new terms, on previously-issued LOAs (treated as negative LOAs in the chart on Page 6).
The past and the road ahead

Figure 5: Reduced activity by innovators in IEEE, following change in FRAND rules

Notes: Chart shows the net rate of licensing Letters of Assurance, at IEEE. Previously-issued withdrawn LOAs are treated as negative additions.
Source: Adapted by CL from Katznelson (2016).

1.30 More common, however, are appeals to outside parties with the power to over-rule the SDOs’ own internal decision-making: such as competition authorities.

1.31 Superficially, it is very attractive for a competition authority to intervene to prevent (for example) the holder of some intellectual property rights embodied in a standard from insisting on a particular license fee from manufacturers of equipment that use that standard. After all, the R&D has already taken place and the invention is there. However, the same considerations would apply to – for example – contracts put in place prior to the construction of a bridge or a pipeline or any other large sunk investment. Once it has been built, it might as well be used for free. However, competition authorities and other public bodies will normally rightly be very reluctant indeed to break contracts in this way, because of the dismal effect this would have on future such arrangements.

1.32 In the case of a contract, with well-defined rates agreed in advance, this reasoning is clear. If one side appeals to a public body to break the contract, that public body should treat such an application with great scepticism. Yet in the area of IP licensing, such calls to break the agreement ex post are common – perhaps because the inevitable uncertainty of invention requires that terms be less specific than they would be in a contract. Nonetheless, it would be poor public policy to accept such appeals, as this would damage confidence that innovators will be rewarded fairly, which must lead to a decline in invention.

1.33 Furthermore, as our report shows, such a change would have wider economic effects. Economists understand very well what an innovator and a manufacturer will do if they cannot commit to dealing with one another fairly in a market for innovation, after each has invested. They will merge instead, thus eliminating any uncertainties that they might create for one another. Yet to do this would be to lose the benefits that we have tried to highlight in this article. Without trust in standards and the institutions that support them, the mobile industry and others like it would carry on – but they would change. Instead of seeing the huge variety of producers of devices and still wider variety of innovators contributing technology, we would see a few vertically-integrated firms dominating the industry. The evidence we have compiled suggests that this would be a step backwards: leading to slower innovation and less competition.

A world without collaborative standard-setting?

1.34 A world without standards is inconceivable but as we have seen, there are several different ways of setting those standards. Can we imagine a world in which the mobile phone industry depended on a single company as ‘gatekeeper’ for a key technology, such as wireless communications standards, as the proprietors of O/S are for personal computers?

1.35 Without suggesting these figures are any other than estimates, we have tried to do so. Mobile technology would presumably have been adopted more slowly. We know that it took seven years longer for 75% of the US population to start using PCs than it did for mobile phones. Quality would have suffered too. Today, 4G data services allow us to access high speed internet using our mobile phones. In 2014, 4G speeds were around 300MBps. Taking one economic study’s estimate of the effect of monopolised standards, speeds would have been around 20% slower; 250 MBps compared to 300 MBps.
in 2014\(^6\). If handset prices had kept pace with PC OS prices, they would be almost twice as high today\(^7\).

1.36 If there had been a proprietary monopolist controlling the wireless communications technology, then it seems reasonable too to guess that the world’s competition authorities would have spent much time investigating its conduct.

1.37 Alternatively, suppose national governments were the gatekeepers for mobile telephony standards, as they are for TV broadcasting. Perhaps manufacturers, network owners and governments in Europe, North America, East Asia and so on would agree incompatible standards and hamper licensing of ‘foreign’ producers in core markets. These regional standards would act as trade barriers, fragmenting the global industry, reducing innovation and competition. With less competition there would be weak pressure on prices: we estimate handset would cost more than twice as much, perhaps over $600 per phone\(^8\).

1.38 The longer term effects are harder still to estimate. It is possible that technology adoption and penetration rates could have been still faster with the government encouraging the use of the national technology\(^9\). However, without global competition the industry would surely be less efficient, and much less innovative and dynamic in the longer term. A few regional ‘champions’ would be responsible for R&D. Firms dependent on state protection increasing devote their efforts to lobbying rather than innovation.

1.39 We suspect that the biggest differences, in a world without collaborative standard-setting through SDOs, would be subtle and emerge only slowly. The large mobile telephony industry — and many others — would be less dynamic, less open to new ideas and disruptive change. Consumers would not merely have slower phones: they would have phones that do much less, because they would mainly do only those things imagined by the vertically-integrated phone manufacturers. It is not only consumers who would be harmed. Career paths within the mobile phone industry would be harder to obtain and more of a linear progression, with fewer mavericks, iconoclasts and entrepreneurs. In short: life would be much less fun.

Conclusions

1.40 We have found that the success of industries needing technological standards depends crucially on the gatekeeper — the organisation that develops and updates the standards. Industries in which Standard Development Organisations act as gatekeepers seem to be more competitive and innovative than those in which a single private company or the government plays that role. The SDOs and the licensing arrangements they support enable a ‘market for technology’, in which smaller and specialised technology providers can thrive. However, to be effective this system depends on achieving a balance of incentives between innovators and implementers — and not undermining confidence by changing that balance once one or other party has made irreversible commitments.

1.41 As a matter of sound economic policy, therefore, competition authorities and others should take a very sceptical attitude to complaints that steps to enforce FRAND principles are anti-competitive. Harm to this system will only result in vertical integration, closed systems and proprietary technologies — the very opposite of what competition authorities should want.

1.42 This is important not merely to preserve the dynamic and effective mobile telephony industry that we currently have. In future, communications technologies are likely to appear in many, many more products in the ‘Internet of Things’. As more industries start to depend on communications technologies, they too will participate in the collaborative standard development process. On the evidence we have seen, for how those processes have driven innovation and competition in the mobile telephone industry, that will be no bad thing.

---

6 Based on a study of hand-held PCs with very different architectures by Boudreau (2008).
7 Based on a comparison of the average of the mobile telephony prices from 1998-2016 (TIA data from Byrne and Corrado 2015; Koenig 2016) and telephone equipment prices from 1998-2016 (Galetovic et al. 2015) with the average of equivalent scenarios generated using the decline in Apple PC prices over the first five months following product launch (Copeland and Shapiro 2018) and PDA OS licence prices from 1990-2004 (Boudreau 2008).
8 Based on a comparison of the average of the mobile telephony prices from 1998-2016 (TIA data from Byrne and Corrado 2015; Koenig 2016) and telephone equipment prices from 1980-1997 (Galetovic et al. 2015) and the FRED Producer Price Index for radio/TV communications equipment manufacturing (2003-2017) in the US.
9 Based on a comparison of mobile telephony adoption rates and TV adoption rates (DeGusta 2012).
BELGIUM
Brussels
23 Square de Meeus
7th Floor
Brussels, 1000
+32.2.274.22.50 main
+32.2.274.22.69 fax

FINLAND
Helsinki
Aleksanterinkatu 15 B
6th Floor
Helsinki, 00100
+358.9.3780.2644 main
+358.9.586.5030 fax

FRANCE
Paris
22 Place de la Madeleine
4th Floor
Paris, 75008
+33.1.53.05.36.15 main
+33.1.53.05.36.16 fax

GERMANY
Berlin
Friedrichstraße 88
Berlin, 10117
+49.30.408.173.050 main
+49.30.408.173.450 fax
Düsseldorf
Kö-Bogen
Königsallee 2b, 5th Floor
Düsseldorf, 40212
+49.211.88.242.235 main
+49.211.88.242.200 fax

SPAIN
Madrid
Paseo de la Castellana 7
9th Floor
Madrid, 28046
+34.91.586.10.00 main
+34.91.586.10.59 fax

UNITED KINGDOM
London
200 Aldersgate
Aldersgate St.
London, EC1A 4HD
+44.20.3725.9000 main
+44.20.3725.9099 fax

About Compass Lexecon: Compass Lexecon is internationally recognised as a leading economic consulting firm with preeminent competition, finance, intellectual property, international arbitration, and energy practices. With more than 425 professionals in 20 offices around the world, Compass Lexecon offers a global perspective on economic matters. For the past 10 years, Compass Lexecon has been ranked as one of the leading antitrust economics firms in the world by the Global Competition Review. To learn more about Compass Lexecon or to find one of our professionals, please visit www.compasslexecon.com.