Android in Europe

Benefits to consumers and business

Prepared for
Google

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compelling economics

About this report

Google commissioned Oxera to examine the benefits that Android offers to consumers, app developers, device manufacturers and the wider digital industry across Europe.

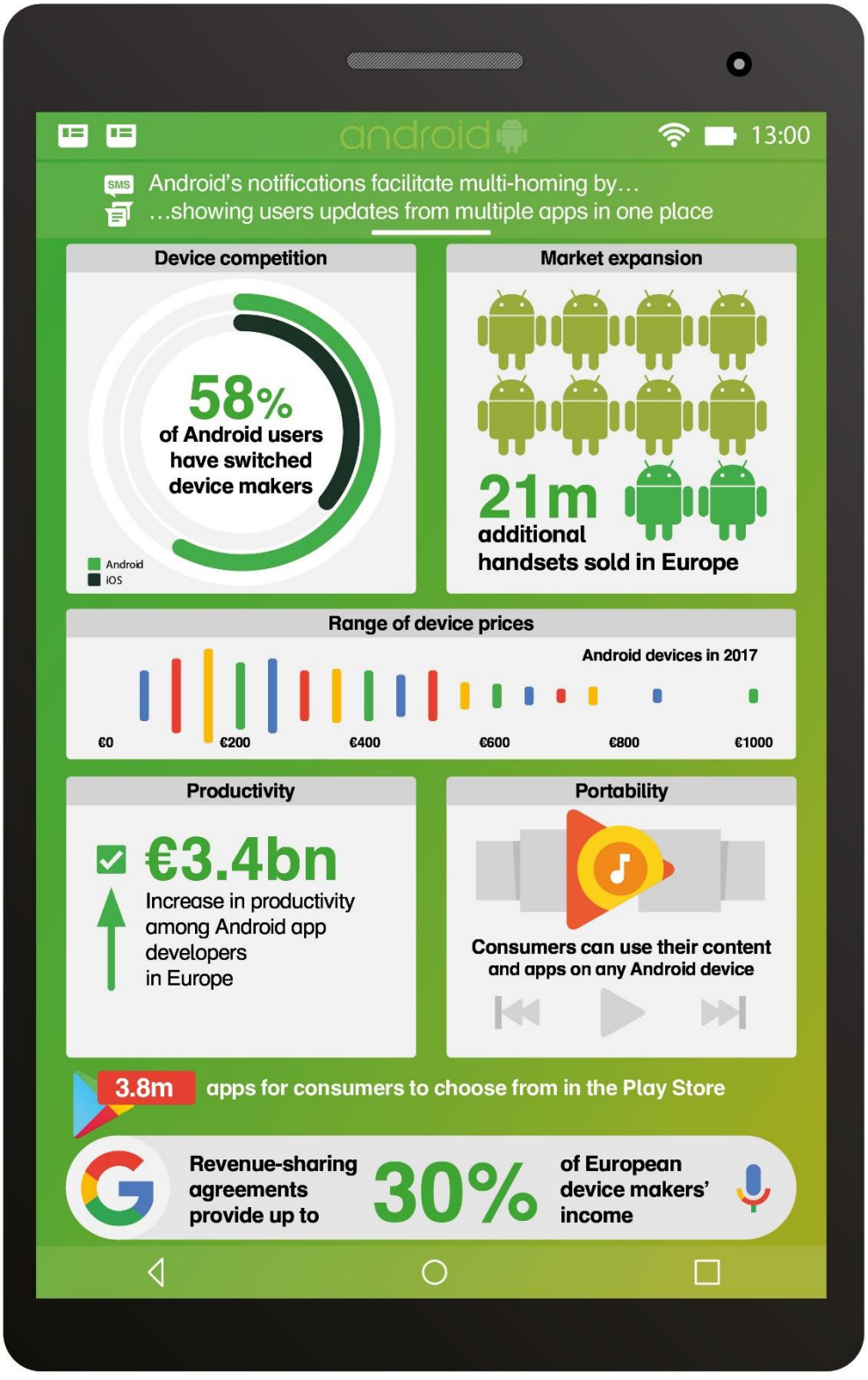
Working with Kantar Media, a consumer research firm, we conducted an online survey of 6,000 smartphone users across four EU countries (Finland, France, Germany and Romania) to understand why consumers choose Android.

Similarly, working with Kantar Millward Brown, a business-to-business research firm, we surveyed 75 European app developers and 10 European device makers to understand the advantages for their businesses of working with Android.

In reaching our conclusions, we also draw on existing public domain data and research, as well as insight from Google. Importantly, this report is not intended as a complete cost–benefit analysis of using Android; and makes no attempt to identify or quantify any possible negative impacts that Android might have.

Our research findings are presented in the main report, while the full methodologies and source references for all our quantitative analysis can be found in the appendices.

Contents


android
13:00
Android's notifications facilitate multi-homing by…
…showing users updates from multiple apps in one place
Device competition
58%
of Android users have switched device makers
Android
iOS
Market expansion
21m
additional handsets sold in Europe
Range of device prices
Android devices in 2017
€0
€200
€400
€600
€800
€1000
Productivity
€3.4bn
Increase in productivity among Android app developers in Europe
Portability
Consumers can use their content and apps on any Android device
3.8m
apps for consumers to choose from in the Play Store
Revenue-sharing agreements provide up to
30%
of European device makers' income

Executive summary

Smartphones have become central to our digital lives. We use them to connect with our friends and family, and to access information, entertainment and markets. With competition enforcers increasingly intervening in digital markets and regulatory authorities examining many of the issues that can arise in these markets, it is vital to understand how the smartphone ecosystem generates value for society.

Google asked Oxera to consider the benefits that the Android ecosystem brings to consumers, businesses and digital markets in Europe. In particular, we examine the economic role that Android plays in connecting consumers and businesses. We begin by explaining what Android is, before evidencing the way in which it generates benefits for consumers, app developers and device makers across Europe. Next, we present a short case study on Android Auto, observing how this new branch of the Android ecosystem can also add value. Finally, we conclude by summarising the features of Android that facilitate its success.

What is Android?

12m
lines of open source code

Android can be thought of in several different ways. To consumers, it is widely recognised as Europe's most popular mobile operating system (OS). To developers, it is over 12m lines of open source code, providing a robust foundation for further development and experimentation. To device makers, it is an industry standard and royalty-free platform, ensuring compatible devices access to a wide ecosystem of apps and services straight out of the box. Finally, to an economist, it is a multi-sided platform creating social value as it brings businesses and consumers together, facilitating trade around the globe.

Android is broader than just a mobile operating system; it is an integrated ecosystem, built around a wide base of users, developers and service providers, underpinned by Google's oversight of the 'Android Compatible' standard. Furthermore, Android reach extends beyond just smartphones and tablets. Wear OS opens the Android ecosystem to smart wearables; AndroidTV powers a range of smart TVs and streaming devices; while Android Auto provides driver-focused interfaces for Android in the car.

How do consumers benefit from Android?

The range of devices and choice of apps available with Android gives the ecosystem a broad appeal. Having surveyed 6,000 smartphone users from around Europe, we identified four distinct types of Android user.

i) **Digital natives:** frequent users of the full range of modern smartphone functionality, including communication, information, social media, commerce, productivity, health, entertainment, smart devices, creative, gaming and navigation.

ii) **Confidently connected:** frequent users of communication, information and social media functionality, while experimenting with commerce, productivity, health, entertainment and smart devices.

iii) **Connected but cautious:** less frequent users of communication, information and social media functionality.

iv) **Occasional browsers:** light users of mainly communication and information functionality.

Each type of user has a different level of sophistication and differing wants and needs when it comes to their smartphones. 'Digital natives' tend to be younger, with a good understanding of how to customise their phone and a high willingness to pay for apps. In contrast, 'occasional browsers' tend to be older, with a preference for lower-cost phones, a limited interest in using apps and less interest in paying for apps or customising their handsets.

3.8m
apps available on Android

Since Android runs on a wide selection of devices at a range of price points, the ecosystem can cater for both these ends of the spectrum, and everyone in between. Importantly, as Android provides a consistent OS across all these devices, the economies of scale and scope attract a wide range of competing app developers. With 3.8m apps currently available (nearly 2m more than iOS), Android users benefit from a long tail of niche apps, with an increased choice set.

Android's user interface design also plays an important role in enabling the vibrant ecosystem, facilitating multi-homing by users across a selection of apps providing similar services. For example, system notifications allow users to multi-home on several different messaging and social media apps while still having a single 'port of call' for new information, regardless of its source.

58%
switched to a competing device maker

Android also facilitates choice and competition in devices. Purchased apps and content are easily portable between devices, meaning that Android increases the scope for users to switch between devices as their needs develop or new offers are launched in the market. We find that 58% of Android users switched to a device from a

different manufacturer when they last changed their phone (compared with 36% on iOS).

21m

extra handsets sold in Europe in 2017 due to free licence

Furthermore, by making Android freely available to device makers, Google has helped to reduce the cost of smartphones. As well as building a wider user base for app and service providers to cater for, Android being offered free of charge has allowed more consumers to enjoy the benefits of smartphones at an appropriate price for them. We estimate that, in 2017, the free Android licence resulted in around 21m more handsets being sold in Europe than in a scenario in which Google charges device makers, and hence consumers, a fee for the use of the Android operating system.

What does Android offer to app developers?

For developers, the large, global Android user base provides the scale necessary to ensure commercial viability for developers—particularly for the long tail of smaller, bespoke apps and services. Additionally, a number of system services offered by the core Android OS, as well as others available on Android via the Google Play Services bundle, can help developers attract users and monetise their apps. For example, Android's in-built finger-print authentication allows app developers to provide secured apps without needing to develop custom security measures; while Google Pay makes it easy for any app developer to accept in-app payments using stored credit card details via a system that consumers already know and trust.

App developers also benefit from Google's efforts to reduce the fragmentation of Android across devices. Fragmentation occurs if device makers modify the Android open source code (known as 'forking') to create bespoke versions of the OS that are incompatible with the core version of Android that Google released. Google seeks to limit this fragmentation by asking device makers to enter into an 'Android Compatibility Commitment'. For a device to be 'Android-compatible', it must conform to a minimum standard of compatibility with the core Android APIs. Moreover, the device maker must commit not to ship any devices running Android forks. However, Google's core compatibility baseline leaves scope for device makers to create differentiated OS by adding their own APIs on top of core Android. Meanwhile, the Android OS has the benefit of guaranteeing developers that their app will run on the vast majority of Android devices, giving the developers the reach required for commercial success without adding the need for costly testing and modifications.

In providing a focal technology around which a wide community of developers and device makers can congregate, Android enhances the productivity of the entire app development sector through a 'virtual agglomeration' effect. This stems from the knowledge spillover that occurs when professionals work together on closely related products and services. We estimate that virtual agglomeration around the Android technologies has led to an 8% productivity increase among app developers, worth around €3.4bn per year in Europe.

€3.4bn

of increased productivity among app developers

Why do device makers choose Android?

For device makers, Android offers the chance to run a well-maintained, robust and thoroughly tested OS on their device at no additional cost. As well as reducing production costs, the use of a ready-made OS reduces the time to market for a new product. How much device makers save depends on their scale and product range. Having surveyed 10 European device makers, we find savings of at least €15,000 from choosing Android, with some reaching up to €20m in cost avoided. For smaller device makers, choosing Android allows them to offer their customers instant access to the wider app and service ecosystem. Without Android, each new device maker would need to build its own catalogue of apps and services, which is expensive and takes time to establish.

Up to

€20m

in cost savings for European device makers

As well as saving money and providing a richer experience for the users of devices, Android allows the device makers to cross-subsidise the cost of their devices through a revenue-sharing agreement (RSA). Under the RSA, the device maker takes a share of any revenue generated by Google searches conducted from the device. We find this revenue share to be material, with our sample of European device makers reporting that this revenue is worth between €2m and €800m (depending on the device makers' scale).

Up to

€800m

from search revenue-sharing

Case study: Android Auto

Although best known as a smartphone OS, the Android ecosystem reaches beyond just mobile devices. In 2015, Google launched Android Auto, an app that provides a simplified Android interface for drivers. The app can be run stand-alone on any Android smartphone or can be connected to an Android Auto-compatible vehicle, at which point the interface is projected onto the built-in display and the device can be controlled from the vehicle's standard infotainment system hardware controls. More recently, Google has extended its offering, with the introduction of Android Automotive, an in-car infotainment OS that does not require a connected smartphone to function.

In using Android Auto, consumers benefit from access to their favourite apps and services through a familiar user interface. As well as providing users with a range of in-car information and entertainment, the continuity provided by Android Auto leads to increased safety, as drivers find the familiar controls easier to navigate.

Car manufacturers also benefit from offering customers a higher-quality, more integrated experience, while saving money on the development and maintenance of the infotainment OS. For app developers and service providers, Android again reduces fragmentation between hardware devices. There are already hundreds of different Android Auto-compatible vehicles in the market, with varying controls and display formats. The open APIs of the Android platform make it easy for developers to access these users, allowing any app provider to write a single code that will run across any Android Auto-compatible hardware.

Conclusions

The Android ecosystem plays an important role in Europe's digital economy, as a multi-sided platform bringing together businesses and consumers across a range of devices. The ecosystem's success rests on creating a virtuous circle of growth by stimulating both 'sides' of the market. Increasing user numbers attracts app developers and service providers, which in turn attract more users, so continuing the growth. This virtuous circle was made possible by a number of key product design and business model decisions by Google.

- By licensing Android to device manufacturers free of charge, Google reduced the price of Android handsets, so increasing its accessibility for users.
- By providing an integrated ecosystem that minimises lock-in, Android facilitates device switching and stimulates competition between handset makers, resulting in a wide choice of features and price points for consumers.
- By minimising fragmentation between devices, Google ensured app developers could tap into the large Android user base with 'write once, run anywhere' code, allowing even niche apps to reach commercial scale.
- Finally, by making the code open source and supporting a wide range of popular programming languages, Google maximised the developer community and enabled the re-use of existing skills and code, leading to greater productivity and innovation on the platform.

1 What is Android?

While often thought of as a 'type' of smartphone or tablet, Android is an open source mobile operating system (OS) from Google that powers a range of devices from multiple manufacturers.

When considering the impact of Android, we should look at several perspectives. To a consumer, Android is a user interface, allowing people to interact with their devices. To a developer, it is an open source code base, helping them develop better software for a wider audience. For a device maker, it is an industry standard, ensuring their device's compatibility with the wider Android ecosystem. While, to an economist, it is a multi-sided platform, creating social value by providing a place for consumers and businesses to trade.

1.1 Android to consumers

For consumers, Android provides a familiar user interface and access to a diverse ecosystem that offers an array of apps and services across a range of compatible devices, from a variety of manufacturers.

A familiar interface

Android provides the base software and user interface through which 74% of smartphone users in Europe access their apps and content throughout the day.[1] In recent years, Android has expanded its reach to include other smart devices, such as wearables, TVs, household gadgets and automobiles, giving users access to their apps and content in more convenient ways, while preserving a familiar user experience.

A trusted ecosystem

With Android, consumers also gain access to the wider Play Store ecosystem, through which they can access 3.8m compatible apps covering everything from social networking to navigation, health, productivity, entertainment and gaming.[2]

As well as apps, the Play Store includes entertainment content in the form of music, videos, books and magazines. Consumers can purchase content easily and securely—both from the Play Store and from third-party apps—using their card details stored in Google Pay.

With 2.3bn users worldwide, Android provides a continued incentive for developers and producers to keep bringing ever-better apps and content to the platform.[3]

A range of choice

As an open OS, available across a range of devices, Android offers consumers unparalleled choice over how and where to access their preferred apps and services.

Within a given device, consumers have the freedom to remove and replace the vast majority of preinstalled content and can change default system services such as the search engine, browser, voice assistant, etc.

Figure 1.1 What is Android?

Source: Oxera.

[1] GlobalStats statcounter, August 2018. See http://gs.statcounter.com/os-market-share/mobile/europe.
[2] According to Statista (Q1 2018) based on app figures. See https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/.
[3] 2.3bn based on interpolation between the number of devices in 2014 and 2017 announced at the Google I/O developer conference.

Meanwhile, by ensuring the compatibility and portability of a user's apps and content across a range of devices from competition manufacturers, Android helps prevent lock-in and allows consumers to choose a device that best suits them and their needs.

1.2 An open source code base

Android is an open source software stack, built by a community of professionals and enthusiasts, available for anyone to download and customise. The core OS is thought to be made up of around 12m lines of code, equivalent to adding up all lines of code from the support systems of both a Boeing 787 *and* the Mars Curiosity Rover.[4]

Initially developed by Android Inc. over a modified version of the Linux Kernel, the OS was sold to Google in 2005, after which it was made open source. This open source 'bazaar' model helps the Android OS to develop rapidly, building on the needs and interests of a wide community of contributors.[5] However, Google retains stewardship over the Android platform, ensuring that each new version of the OS is fully secured and tested.[6] This is in contrast to the 'cathedral' model adopted by Apple with the release of the first iPhone in 2007.[7] With the iPhone, Apple keeps control of all aspects of the direction and development of both the hardware and underlying OS.

In 2007, the Open Handset Alliance was formed, bringing together device makers, telecoms operators, chipset makers, software firms and others. Through the Alliance, these parties all contribute to the development of the Android OS and influence the direction taken by the wider ecosystem.

1.3 An industry standard

In markets where network effects exist, such as mobile OSs, common standards can provide several benefits to consumers.

There is a direct effect from interoperability, ensuring users can interact more easily and reliably port files and media between devices.

Then there is an indirect effect from variety, as having a common standard attracts more device makers, app developers and service providers who wish to serve a wide user base.

Lastly there is a benefit from certainty, as consumers do not need to fear becoming stranded with a technology that fails to reach scale and is later abandoned by its creators.

These effects typically lead to increased competition *within* the standard, as consumers are not locked in to a single device maker or app provider. The Android standard ensures that smartphones produced by any one of the 1,300 compatible device makers around the world will work seamlessly with the wider Android ecosystem.[8]

This compatibility is made possible by the voluntary Android Compatibility Commitment (ACC), which device makers can choose to agree to if they wish to be certified 'Android-compatible'. As one app developer described it when asked how Google's APIs compare to those of third parties:[9]

Google are very good at what they do, so they are always the flag bearer

App developer, UK

Table 1.1 Comparison of mobile operating systems

	Android	iOS	Windows Phone	RIM	Palm	Symbian
Free OS	✓	✓	–	–	–	–
Unified user interface	✓	✓	✓	–	✓	–
Limited or no fragmentation	✓	✓	✓	✓	✓	–
Offered in wide device range	✓	–	✓	–	✓	✓
Multiple app stores	✓	–	–	–	–	✓
Easy to attract developers	✓	✓	–	–	✓	–

Source: Oxera.

[4] Information is Beautiful (2015).
[5] The concept of 'bazaar', introduced by Eric Raymond in *The Cathedral & the Bazaar* (1999), refers to an open source development approach, with independent (often volunteer) developers suggesting improvements they would like to see.
[6] See https://source.android.com/setup/start/codelines
[7] In contrast to the bazaar, Raymond describes a 'cathedral' model, with all aspects of the development centrally planned, under the close control of the development team, with rigorous testing and official beta release cycles.
[8] See Pichai (2018).
[9] Survey of 75 app developers conducted by Kantar Millward Brown for this study. See also Appendix A4.4.

1.4 An economic platform

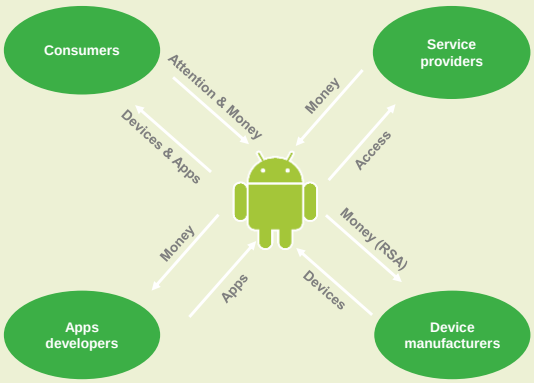
More than just a technology, the Android ecosystem represents an important economic platform that creates value by bringing together four parties:

i) consumers;
ii) device makers;
iii) app developers; and
iv) service providers.

In economics terms, Android can be described as a multi-sided market. This form of market differs from regular markets, in that the value one user gets from a platform depends (at least in part) on the number of users on the other side of the platform. In the case of Android, all four parties contribute to, and benefit from, the platform ecosystem in the following ways.

- Android's consumers represent a substantial, global user base. This user base makes an attractive market for device makers, app developers and service providers to tap into. In return, these consumers benefit from access to a wide range of compatible devices at various price points, with supported apps and services (often free of charge).
- Device makers provide consumers with a wide choice of mobile devices and other smart devices running the Android OS. Device makers benefit from the royalty-free Android licence; and some even *receive* funds from Android through Google's revenue-sharing agreements (RSAs).[10] This allows device makers to focus on developing innovative hardware, knowing there is an established ecosystem they can tap into; while the RSA further incentivises them to compete for users.
- 1.6m European app developers have contributed more 3.5m apps to the Play ecosystem.[11] Developers benefit from having a vibrant marketplace for their apps, and from access to the suite of Play Services tools (location, authentication and notification services) free of charge.
- Many service providers give consumers access to a range of useful functions—such as music and video streaming, video calling, social media or navigation—which are also one of the main ways consumers benefit from having a smartphone. Others provide advertising or e-commerce services that help businesses earn revenue from the platform. Both consumer service and business service providers benefit from access to the large, global Android user base.

Android as a platform



Multi-sided platforms emerged as a topic in the academic literature in the mid-2000s with the work of Jean-Charles Rochet and Jean Tirole (2003). An overview of the principles of platform economics can be found in Appendix A1.

Markets with network externalities are characterized by the presence of two distinct sides whose ultimate benefit stems from interacting through a common platform.

Rochet and Tirole (2003)

The literature highlights two defining traits of multi-sided platforms:

i) their role as intermediaries between two or more types of users; and

ii) the fact that the value of the platform to one user type depends on the number of users of the other type(s) on the platform.

These characteristics give rise to indirect network effects and introduce new considerations when determining the optimal pricing structure.

In setting the price for a particular user type, platforms take into account not only the marginal cost of additional users, but the gains that platforms can make due to the higher demand from the other category of users (i.e. the indirect network effects). One implication is that charging consumers below the marginal cost, or even not at all, may be optimal overall.

[10] See section 4.2 for further details.
[11] See Pichai (2018).

Consumers get more value from the platform when there are more app developers and service providers; while app developers and service providers gain value from the platform having many users. Thus, the more users there are, the more app developers will join, which feeds back to user demand, which in turn increases the platform value for app developers. In economics, this virtuous circle is known as an 'indirect network effect'.

Importantly, network effects can work in both directions. When a platform is growing, these effects serve to promote that growth, as more and more users are attracted on both sides of the platform. However, if a platform stagnates, network effects can accelerate that platform's decline, as users on each side start to go elsewhere.

1.5 Lessons from Symbian

The idea of an open source mobile OS was not entirely new at the time of Android's launch. After Nokia acquired full control of Symbian Ltd, a software development and licensing consortium, in 2008, the Symbian Foundation was formed to make the Symbian OS open source and royalty-free.[12]

By that point in time, Symbian already had many novel characteristics that would later become standard for a successful mobile OS. It provided Internet access, allowed third-party apps and had anticipated the need for touchscreen functionality. Furthermore, it was a licensable (and later open source) OS, used by several device makers.

Despite this, Symbian's share fell from around 70% of all European handsets in 2008 to less than 40% in 2010, before dropping to zero by 2014.[13] This decline was later attributed to a number of business model choices and technical constraints that made it difficult for an ecosystem of third-party apps and services to grow around the Symbian OS.[14]

There were three things that really held Symbian back: (i) having to charge a licence fee; (ii) not having a unified and complete UI [user interface] developed with the OS; and (iii) the fragmented app/ecosystem community

Nigel Clifford, Head of Symbian, 2005–08

By 2007, only 10,000 apps had been created for Symbian.[15] Compare that to the 16,000 available on Android by the end of 2009 (Android's first full year) and more than 3.5m in 2018. Significant fragmentation within Symbian made for an unappealing environment for app developers.

First, despite running on a common OS, Symbian had four different and incompatible user interfaces (UIs): S60, S80, S90 and UIQ.[16] In effect, this required a developer to write four essentially separate apps if they wanted to cover all Symbian models on the market.

Second, Symbian had no centralised app store for developers to distribute their apps. Some device makers had their own app stores, but these were time-consuming to establish and costly to maintain. While there were eventually some initiatives to integrate the UIs and app stores, these came too late to undo the fragmentation among device makers.

Learning from the Symbian experience, Google took several steps to foster a vibrant ecosystem around the new OS:

i) it offered Android to device makers free of charge right from the start. This helped it attract a wide user base for its emerging ecosystem;

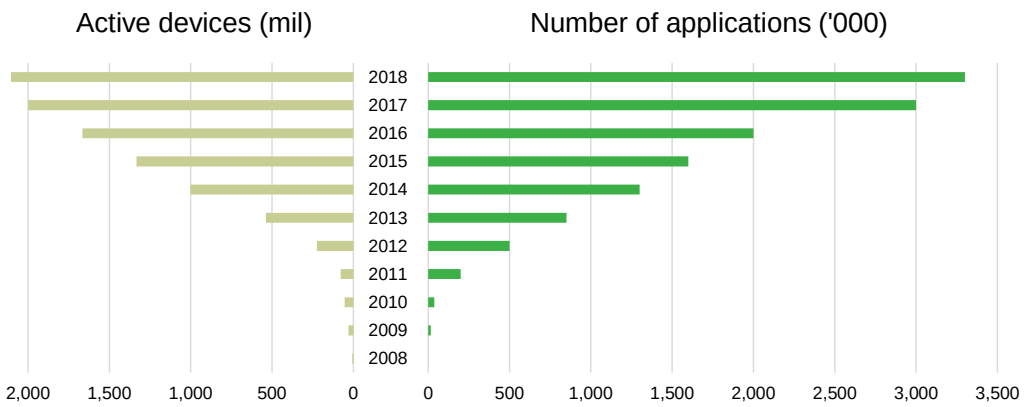
ii) it offered a unified UI, which meant that consumers could be familiar with how Android worked and looked, regardless of the brand of handset they bought;

iii) it limited the fragmentation of the ecosystem through the Android Compatibility Commitment.

This approach proved to be successful for Google. Figure 1.2 below shows the exponential growth of the Android ecosystem since its launch in 2008. By 2018, over 2bn users globally had access to more than 3.5m apps, on more than 24,000 mobile and smart home devices.[17]

[12] ZDNet (2013).
[13] Based on Oxera analysis of IDC data (see Figure 2.4 and Appendix A2).
[14] Nigel Clifford, as reported in ZDNet (2013).
[15] Pichai (2018).
[16] ZDNet (2013).
[17] 24,000 devices running Android according to Pichai (2018); over 2bn users according to Tech Crunch (2017).

Figure 1.2 Number of Android devices and apps on the platform



Note: For years without data, the number of active devices is linearly interpolated. The number of Android devices in 2008 is assumed to be equal to the number of shipped devices.

Source: Oxera based on Statista and announcements at the Google I/O developer conference.

2 How do consumers benefit from Android?

From communicating with text messages, social media updates and video calls to controling smart homes and travelling with navigation apps and recommendations services, mobile devices have become integrated into all aspects of our daily activities.

As a leading platform providing access to these apps and services, Android offers a range of benefits to consumers throughout Europe. The wide variety of devices and selection of bespoke apps offered at a range of prices maximises the chances of consumers finding something suitable for their needs and budget.

2.1 Who uses Android?

Today, more than 2bn people around the world have an Android device, which they use in a variety of ways.

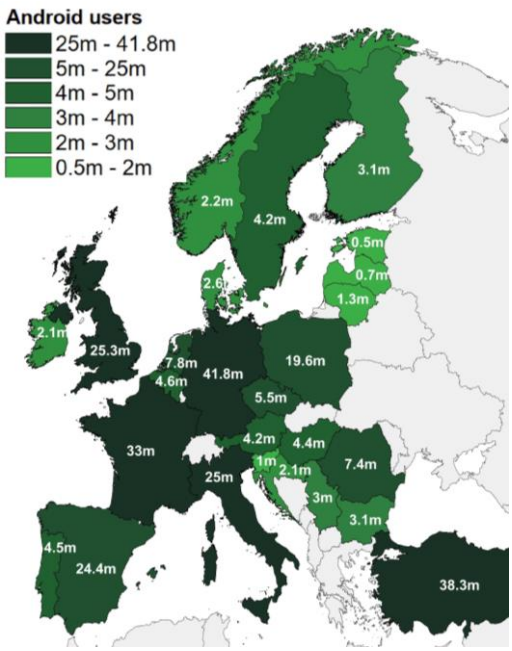
To understand what consumers value most about Android, Oxera commissioned Kantar Media to survey 6,000 smartphone users across Finland, France, Germany and Romania.

From the survey, we identify four distinct groups of Android users, based on the frequency with which they use different types of app. At one end of the scale are the 'digital natives' who use their smartphones and other smart devices extensively for a wide range of tasks and entertainment purposes. At the other end are the 'occational browsers', who use their smartphones infrequently and, even then, tend to use only the basic messaging and web browsing functionality. In between we find a cohort of 'confidently connected' users, and 'connected but cautious' users, who engage with their smartphones relatively often, but use only a subset of the full functionality on offer.

Digital natives

Digital natives represent 12% of the sample, and report using all 18 types of apps 'frequently'.[18] This group is characterised by young users than in the other groups who, on average, also own more expensive smartphones. With an average of 28 apps on the phone, of which 8 are used regularly, this group is well connected and informed. In addition, 42% of users in this group have at least one paid app. Of the four countries surveyed, Romanians are most likely to be classified as digital natives.[19]

Figure 2.1 Android users in Europe



Source: Oxera based on Statista and statcount.

Confidently connected

Representing 43% of the sample, this is the largest of the four groups. With demographic characteristics similar to the 'digital natives', the 'confidently connected' users have an average of 30 apps on their phone and regularly use 8 of them. Typically they use only the most popular apps, such as communications and social media, Internet search and browsing, and free content services. Other more specialised and paid apps are used, but less often. A quarter of these users have at least one paid app.

Connected but cautious

This is the second-largest group, at 30% of the sample. While similar to the 'confidently connected' in terms of their usage of shopping, reading free content, subscription content and email apps, the main difference is that this 'connected but cautious' group use less social media, messaging and streaming of free content, and are less likely to control other smart devices with their Android device. Users in this group are generally older than in the other groups and typically own less expensive phones. The lower usage is also reflected in fewer regularly used apps (6 on average) and the lower percentage who have at least one paid app (16%).

[18] The 18 types of apps used are: searching online, shopping, reading free content, social networking, messaging apps, emails, photo/video sharing, streaming free content, streaming paid content, games, educational, business, utilities and banking, navigation, recommendations, fitness and health tracking, reading paid content, and controlling smart devices.

[19] The share of Romanians in the first user group appears to be relatively high. This may have been driven by a sample selection effect leading to users with active usage of smartphones being more motivated to respond to the survey. An alternative explanation could be that there is a selection effect at the level of smartphone users in Romania, where smartphone ownership is less ubiquitous, meaning those who do own one are more likely to be active users.

Occasional browsers

Lastly, 15% of the sample are classified as 'occasional browsers'. They have an average of 18 apps on their phone, of which 4 are frequently used. Occasional browsers tend to be older than the users in the other groups and own less expensive phones. They mainly use messaging and email and do so less frequently than the other user groups. In addition, they are less aware what brand of smartphone they have.

2.2 Consumer expectations

In Europe, people conduct many of their daily activities online, including socialising, business, learning, and entertainment. For many consumers, their home PC or laptop was the first device that allowed them to connect to the Internet. However, with the expansion of smartphones, 12% of the Android users we surveyed said that they first accessed the Internet regularly using a mobile device. For the younger generations, mobile devices are even more important as a gateway to the Internet, with 84% of our survey respondents having used their smartphone to access online services while on the move.

When asked what factors influence their decision when choosing a new phone, Android consumers reported that price, technical specifications, and privacy/data protection are the three most important factors, closely followed by security and updates. This suggests that consumers value the additional competition in devices—in terms of both price and features—that Android creates. Different users can better match their wants and needs to their budget, while still having a familiar and trusted OS.

As technology evolves and the number of connected devices increases, interoperability is becoming an important expectation of all users. Of the Android users surveyed, 91% said that they also use other smart devices, while more than half of them (56%) reported connecting their phone to these devices. In addition, the ability to do so is a factor that 44% of them considered before buying a new phone.

The variety of devices in the Android ecosystem allows users to switch with minimal effort from one Android-compatible mobile device manufacturer to another, as their data, preferences and apps can all be moved between devices. Meanwhile, their other Android-compatible smart devices (such as a wearable) also connect seamlessly to the new device.

2.3 Competition in apps and services

Almost half of the Android users surveyed have at least 21 apps on their smartphone and regularly use more than 5 apps (see Tables 2.1 and 2.2). This variety is enabled by the access through Android OS to over 3.8m apps through the Play Store—almost twice as many as are available on iOS in 2018. This can be attributed, at least in part, to the openness and reach that Android has achieved. A companion survey found that 32% of Android developers identified openness as an important benefit of building apps using the Android OS.[20]

Since Android runs on a wide selection of devices at a range of prices, it attracts a broad base of users with a range of income levels. Android promotes competition in the apps and services markets by offering developers easy access to these users, while several specific design decisions ensure users have the freedom to choose which apps and services they use. This includes promoting multi-homing, allowing users to change default services, allowing competition between app stores on the platform, and allowing users to replace pre-installed apps.

Multi-homing on messaging services

Many users download multiple apps of the same type. For example, for messaging apps, 83% of 18–24-year olds in the UK use Facebook, 62% use Snapchat and 60% use WhatsApp. These apps alone account for an average of two messaging apps per person.

Table 2.1 Number of apps used regularly

Number of apps	Android	iOS
0–5	58%	43%
6–10	31%	38%
11–15	7%	10%
16–20	3%	5%
More than 20	2%	5%

Table 2.2 Number of apps on phone

Number of apps	Android	iOS
0–10	28%	19%
11–20	30%	28%
21–35	20%	21%
31–40	7%	9%
41–50	7%	11%
> 50	8%	12%

Source: Oxera based on consumer survey.

[20] For further details of Oxera's survey of Android app developers and device makers, see section 3.

The use of more than one app for the same purpose is known as 'multi-homing' and for Android users is made possible by the consolidation of alerts in the Android notifications centre. The convenient aggregation of notifications from multiple messaging apps, for example, means that consumers are able to try out competing apps without forgoing their existing services, thereby reducing the barriers for new providers to enter this market.

Changing default services

To ensure users have a high-quality experience straight out of the box, device makers must configure the Android OS with several default services. These include a default search engine, default web browser and default voice assistant. However, users remain able to change the vast majority of these defaults at any time while using their device.

Take the default search engine, for example. In Europe, there are several alternatives to Google offering differentiated services, such as Bing, Yahoo and DuckDuckGo. Any of these can be set as the default search engine within Android. From the Android home screen, a user can change the default search engine with four taps. In comparison, an iPhone user would take three taps and one scroll.[21]

Furthermore, if an alternative Internet browsing app is installed through Google Play, changing the default browser can automatically change the default search engine, depending on the selected browser's default settings.

Multiple app stores available

While the Play Store ensures there is a central 'hub' to promote a vibrant Android ecosystem (learning from Symbian, which suffered from a fragmented third-party apps market), alternatives are available (e.g. Amazon App Store, Aptoide, GetJar and SlideME) and carry hundreds of thousands of apps.

These app stores can be installed on a device directly from the web browser or may be pre-installed by device makers. Once installed, the openness and unity of Android allows Play Store competitors seamless access to the device's users.

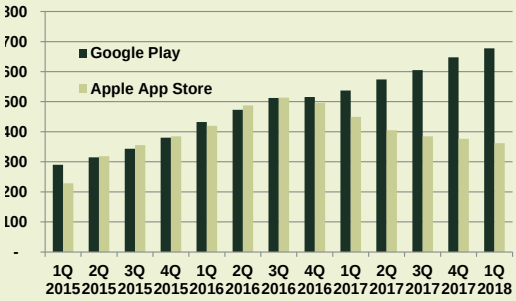
While some app developers choose to single-home in a competitor to the Play Store, many developers prefer to make their apps available in these alternatives as well as the Play Store, in order to target particular market segments and potentially gain more prominence than they can in the fiercely competitive Play Store.

Case study: games

Mobile has become an increasingly important platform for game developers over recent years. Worldwide gaming revenues through mobile OSs amounted to around €49bn in 2017, almost twice as much as the game market revenues on PCs and seven times as much as those obtained through consoles.[1] Revenues are projected to reach €62bn by 2020.[2]

Our study shows that 37% of Android users play games on their phones at least once a day. Developers have met this demand by increasing the number of available gaming apps, particularly through Google Play.

Gaming apps ('000)



Source: Oxera based on Appfigures.

The mobile gaming market is particularly relevant for the apps economy. Although it represents only around 35% of total worldwide downloads, it accounts for nearly 80% of consumer spending on app stores.[3]

Looking ahead, the outlook for the mobile gaming industry seems positive. The strong monetisation potential of games described above is incentivising developers to invest in new, quality mobile games. Indeed, a new generation of games based on augmented reality (AR) technology is arriving, and developers will be able to draw on tools from the wider Android ecosystem to improve the user experience. For instance, the APIs on Android's AR developer kit will allow games to use Google Maps and turn real-life objects, 'GameObjects'.

Notes: [1] SuperData Research. [2] App Annie and VentureBeat. [3] App Annie, and IDC (2018a).

[21] These tests were carried out by Oxera with an iPhone 6s running iOS 11.4 and a Samsung Galaxy S7 running Android version 7.0.

Removal of pre-installed apps

Device makers will typically pre-install several apps on their new devices to improve their user's 'out-of-the-box' experience. This can include apps from third-party app developers, typically as part of an agreement between the device maker and developer. In Google's case, there are several stand-alone apps—including Chrome, YouTube, Maps, Drive and Gmail—that device makers can pre-install.

However, the Play Store offers a wide variety of alternatives apps that compete directly with these Google services, and users, are free to uninstall or disable any apps that come pre-installed.[22] In our survey of Android users, 91% claimed to know how to delete an app and 94% of those have done so from their smartphone. The main reasons given for deleting an app were to remove those that were not being used anymore and to free up space on the phone.

2.4 Greater choice of devices

Android fosters competition between device makers, to the benefit of consumers, by lowering barriers to entry for new, innovative firms, and by making it easier for consumers to switch devices. This increased consumer choice helps keep the price of devices down and quality up.

Having a lot of people building a lot of things covering a lot of price points … makes a big difference

Stephen Baker, talking to *Business Insider*

Faster innovation

Android's open source 'bazaar' model stimulates innovation by allowing a wide community of developers and device makers to build features and hardware that are of interest to them and their target customers, while remaining within the wider Android ecosystem (see also section 1.2).

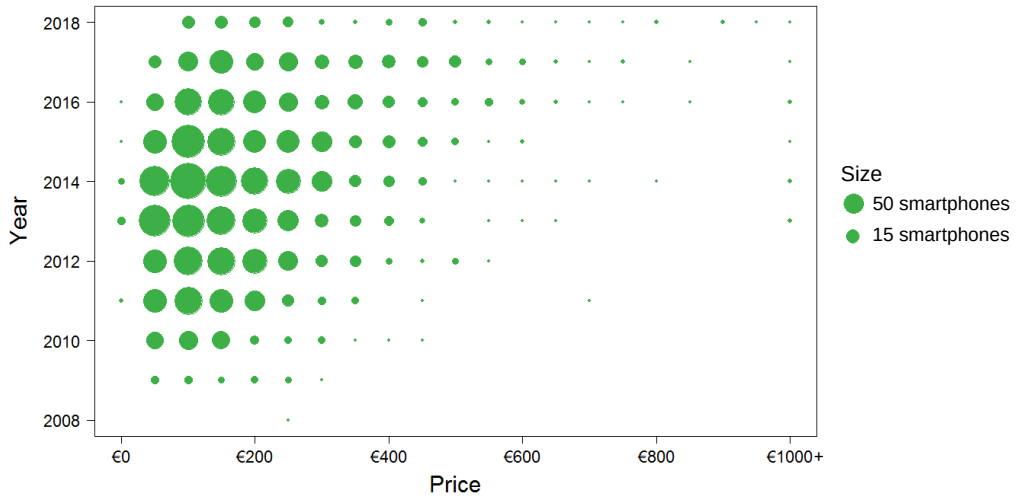
This, together with the stewardship of the innovative Android team, has stimulated a wide variety of, and rapid growth in, Android devices, catering to a wide range of budgets and needs. By 2012 (four years after its first launch), Android was considered as one of the growth engines of the smartphone market.[23]

As Figure 2.2 shows, in the ten years between 2008 and 2018, Android has facilitated the introduction of a large number of devices at prices from around €50 to more than €1,000. Compared with iOS, the wide range of choice offered on Android means consumers are more likely to find a device that offers a good balance between the functionality they need and their available budget.

Easier switching between devices

For the average user, switching between device makers within the same ecosystem is likely to be considered easier and undertaken more often than switching to a device with a different OS. Indeed, our consumer survey finds that 58% of Android users changed device maker when they bought their last smartphone, compared with only 36% iOS users who switched away from Apple.[24]

Figure 2.2 Range of Android devices available each year



Note: The circle's size represents the number of smartphones models, grouped into €50 price brackets.

Source: Oxera based on Teoalida database of 2,714 Android phones released between January 2008 and May 2018.

[22] Some Google apps cannot be uninstalled but can be disabled. This is functionally equivalent, as these apps no longer appear in the app draw, cannot push updates to the user, and cannot run silently in the background.
[23] See *Business Insider* (2012).
[24] Calculations based only on those who had a smartphone before and reported the brands.

Android facilitates switching between device makers by offering a unified user experience and portability of paid apps and content (as well as consumer data held in the cloud). This prevents consumers becoming 'locked-in' to any particular device maker over time.

As Figure 2.3 shows, our consumer survey reveals there is considerable switching by consumers between different device makers that both offer Android. For example, 14% of the Samsung users in the sample moved to Huawei. This offers advantages to the consumers of Android smartphones who are not being locked in to the brand of their device. In addition, 57% of the smartphone users surveyed consider a familiar user experience to be important when choosing a phone. Again, Android's unified OS offers these consumers a more seamless transition between devices and apps.

Lastly, this is likely to benefit lower-income consumers in particular. Table 2.2 shows that it is the low-and medium-priced smartphone users who switch device makers most often; more so than owners of high-priced smartphones.

Table 2.2 Price of phone and switching

	Android		iOS	
	Same device maker	Changed device maker	Same device maker	Changed device maker
Low <€250	35%	64%	67%	33%
Medium €250–€500	46%	54%	59%	41%
High >€500	61%	39%	68%	32%

Source: Oxera based on consumer survey.

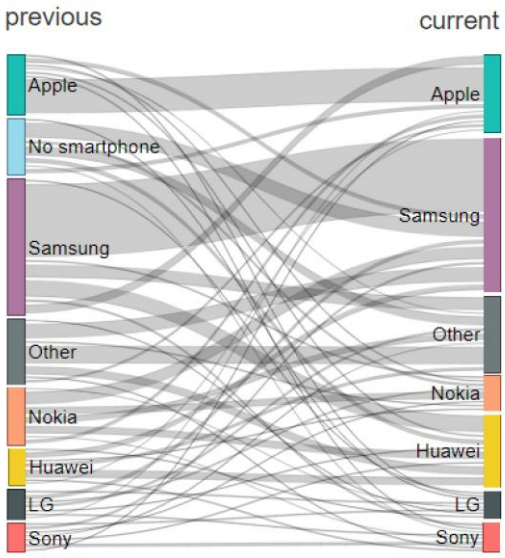
2.5 Greater access to devices

Google does not charge manufacturers to use Android. In fact, through the RSAs, many device makers get *paid* for the use Android on their devices.

As we have seen, there is vibrant competition among device makers running Android. In competitive markets, any reduction in cost to device makers is likely to be largely passed on to consumers as through retail prices. This means that the money that device makers save (or the revenue they receive) from running Android translates directly into lower-price devices for consumers.

To quantify the value of the free Android licence to consumers in Europe, we consider the impact on smartphone sales compared with a counterfactual in which device makers pay a licence fee (or, equivalently, incur the cost of developing their own OS and ecosystem).

Figure 2.3 Switching between device makers



Base: 5,911 survey respondents who reported the brands of their current and previous smartphone.

Source: Oxera based on consumer survey.

We assume a hypothetical licence fee of $25 (€21) (which we also assume would be passed on to the consumer in full, as a $25 increase in the price of a device). This assumed $25 is based on the 2018 price of the Windows 10 licence for a notebook or tablet, as explained further in Annex A2.[25] This Windows 10 price is used as proxy for a mobile OS licence fee for two reasons:

(i) there is no observable 'market price' for a large-scale mobile OS licence, given Android is free of charge and iOS is exclusive to Apple devices;
(ii) the tablet edition of Windows 10 is intended to run similar hardware to a smartphone and is therefore likely to be of a similar technical sophistication (and thus cost).

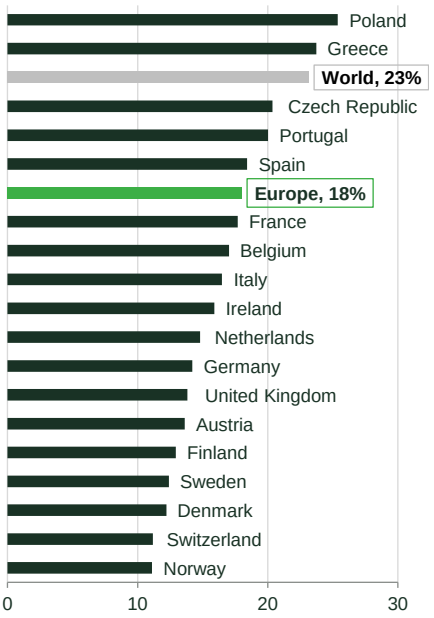
Next, we consider consumers' likely demand response to an increase in the price of their device—referred to in economics as a product's 'price elasticity of demand' (PED). That is, the percentage change in the quantity that consumers seek for a given percentage change in price. PEDs are typically negative, indicating that an increase in price results in a fall in demand (as would be expected). In our base case, we assume a PED of -1.77, taken from a study of the US market.[26] This means that for every 10% by which the price of a smartphone increases, demand will fall by 17.7%.[27]

[25] Bright (2018). The $25 licence cost is equivalent to €21; converted 1.2:1 USD:EUR.
[26] See Zhu, Liu and Chintagunta (2015).
[27] This represents the average PED for handsets across all smartphone types and was found to be a reasonable estimate given the characteristics of the European market and when compared with other estimates from the literature. See also Appendix A2.

Taking these assumptions, along with data on the prices of smartphones available in the market, we estimated the number of handset sales that would have been lost each year if Android were charged for. Figure 2.4 shows the results of our analysis for Europe. We estimate that 21m extra Android smartphones were sold in 2017 alone as a direct result of the Android platform being royalty-free. This represents a market expansion of 18% compared with the case in which device makers had to pay $25 per handset for the OS. With the benefit to consumers of owning a smartphone estimated at around €364 per year,[28] an extra 21m handset sales could increase consumer welfare by around €7.6bn per year.[29]

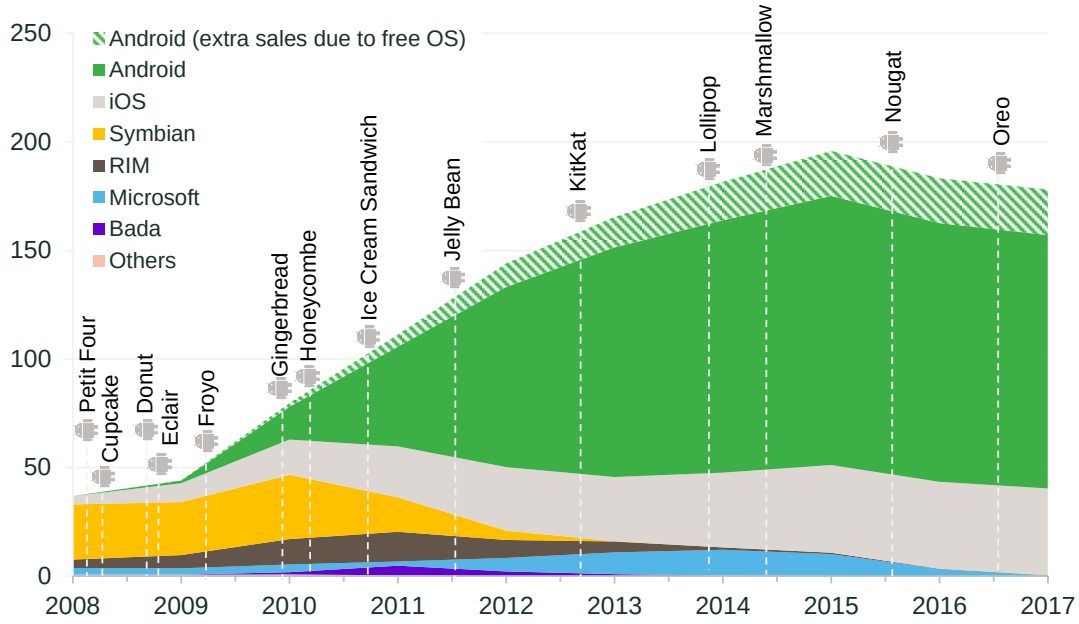
Within Europe, lower-income countries such as Poland or Greece see a larger expansion effect from the royalty-free Android licence than high-income countries such as Finland or Switzerland, as shown in Figure 2.5. This is due to variations in the average price of Android phones sold in different countries, meaning that the licence cost represents different relative price increases.[30]

Figure 2.5 Expansion by country (%)



Source: Oxera analysis using International Data Corporation (IDC) data and an estimate of price elasticity of demand for smartphones.

Figure 2.4 Market expansion effect of free Android OS in Europe (handsets sold, m)



Source: Oxera analysis using IDC data and an estimate of price elasticity of demand for smartphones.

[28] Brynjolfsson, Eggers and Gannamaneni (2018); converted 1.20:1 USD:EUR.
[29] The total value of consumer welfare in Europe was obtain by multiplying 21m extra handsets sold with €364.
[30] For simplicity, a constant PED is assumed across countries and price levels, the value being in line with the 2017 average price level in Europe. To that extent, the market expansion effect might be underestimated for countries with a higher price level and might be overestimated for countries with a lower price level. This is because the absolute PED would be expected to be higher at higher prices. However, demand overall would be expected to be more elastic in low-income countries than in high-income countries, which would be counteracting this estimation error.

For instance, in 2017 Android smartphones sold at the equivalent of $443 (€420) in Norway, $356 (€338) in Germany and $219 (€208) in Poland, while Europe-wide the average price was $290 (€275).[31] A $25 (€21) price increase would therefore represent a 10% price increase in Poland, but only a 5% price increase in Norway. The lowest-income consumers are hardest hit by a price increase, with the result that they respond most strongly with a decrease in demand.

Our analysis does not attempt to account for the fact that lower-price Android phones (due to the free OS) would be likely to have increased the competitive pressure on smartphones outside of the Android ecosystem—in particular, on the iPhone.

Furthermore, it does not attempt to quantify the switching from Android to other providers (again, particularly to the iPhone) that would be expected in the event of an increase in the average cost of Android handsets. However, our analysis does provide a reasonable estimate for the likely scale of expansion in the smartphone market induced by the free licencing of Android.

Finally, we consider how the analysis would change if instead of $25, we assumed an Android licence cost $45—the fee that Microsoft charges for Windows 10 being used on devices with higher storage. In this scenario, the market expansion effect for Europe would amount to 38m extra Android phones in 2017 (an extra 38%).[32]

[31] From the IDC data, we see that the difference in average prices is mainly due to different market shares of lower-price and more expensive smartphone models, while the same models are selling at similar prices across Europe; converted 1.05:1 USD:EUR.
[32] Further scenario tests and a detailed description of the approach can be found in Appendix A2.

3 What does Android offer to app developers?

The app economy in Europe is growing. By early 2017, nearly 2m jobs were related to app development, surpassing the USA for the first time.[33] A significant proportion of these jobs benefit from Android—on a monthly basis, there are twice as many app downloads and three times as many app additions on Android compared with iOS.[34] This has meant that, globally, Google facilitated around US$7bn of revenue to app developers between February 2014 and February 2015.[35]

This section sets out what Android offers app developers. In particular, it explains three key supporting elements: i) commercial scale, ii) non-fragmentation, and iii) virtual agglomeration.

3.1 Our survey of app developers

To understand how app developers benefit from the Android ecosystem, Oxera commissioned Kantar Millward Brown to conduct 75 interviews with Android app developers across four countries in Europe. The sample includes both full-time developers and contractors from small to large firms. The respondents develop various app types, such as entertainment, games, health, productivity, shopping and education.[36]

3.2 Commercial scale

From May 2016 to May 2017, over 82bn apps were downloaded from Google Play, and the number of developers whose apps got more than 1m installs grew by 35%.[37] However, the size of the app economy is difficult to estimate. The European Commission put app economy revenues at €17.5bn in 2013, and recognises the upward trend is likely to carry on.[38]

The number of users on the platform, the attractiveness of an app on that platform, and the possibility to monetise from customers will determine how profitable it can be for a developer to invest in developing for a certain OS.

Scale

The scale of an OS is critical to attract a developers and service providers. Without scale, platforms would need substantial investments to get developers interested in joining. For example, Microsoft had to offer minimum revenue guarantees to some app developers as an incentive to programme for Windows phones.[39]

In addition, sufficient scale is needed for virtual agglomeration to be an effective catalyst of innovation. When it comes to platforms, it is often the case that size begets size. For 56% of the app developers interviewed, the wide coverage offered by the Android platform is one of the most important characteristic of the ecosystem. The developers who work with multiple OSs are more likely to consider the size of a platform an important factor as they have to weight their expected profit for a certain investment on an OS.

I think the main benefit of Android is having a really large user base so you can reach a large audience

App developer, UK

Analysis of the survey identified that the portability of the same app to multiple devices is an important advantage of Android for developers because they can code their app once to run on many devices. In a counterfactual scenario where Android's user base was fragmented across several different OSs, the expected return from any investment would fall considerably as costs increase.

Main advantage: portability to a variety of different devices

App developer, France

The scale of Android is an important factor in choosing which OS to develop for. Of the app developers interviewed, 17% said that, if the number of Android users halved, they would no longer develop for Android; 40% said they would no longer develop if there were only one-quarter of the current users of Android.

As at 2014, 36%[40] of app developers single-homed OS. While the technical costs of porting an app across several OSs can be significant, app developers report that marketing costs are the main barrier to multi-homing. This is because significant resources are needed to be visible in the app store. For these reasons, scaling up quickly allows the programming and marketing costs to be recovered. A more fragmented OS market would lead to a significant number of developers, without the resources to multi-home, being unable to reach enough traffic to make their app profitable.

One-third of the respondents who provided information on the percentage of downloads and revenue in each app store (10 out of 31) said that

[33] Mandel and Long (2017).
[34] Ibid.
[35] Based on information provided to Oxera by Google.
[36] Some of the direct quotations presented in this report have been edited for length, clarity and grammar.
[37] Based on information provided to Oxera by Google.
[38] European Parliament Research Service (2018).
[39] Bass and Satariano (2010).
[40] Bresnahan, Orsini and Yin (2014).

revenues from the Google Play Store are less than proportional to the number of downloads in that store. This in turn means that the per-user value in the Play Store is lower than in other stores. The lower value is explained by the broader demographic appeal of Android, putting emphasis on the scale of the platform to allow app developers to spread development costs across a larger number of users.

Monetisation potential

App developers make money from their apps using three main approaches: including advertising in their apps, installs/subscriptions, and in-app purchases. The first of these—in app advertising—is the most widely used by app developers worldwide and brings the highest revenue (53% of the revenue for games and 76% of revenue for other apps). However, the three approaches are not mutually exclusive, and the same app could include all three. For example, gaming apps receive around 43% of their revenue from in-app purchases and mobile commerce.[41] Our survey of app developers asked how they monetise their apps and verified these patterns.

Android is the most popular device system so I can make more money than on other ones

App developer, Poland

The installs/subscriptions and in-app purchase options require a user base willing to spend money to purchase the app or additional features when using it. Only 22% of the Android users surveyed have bought at least one app, versus 40% of iOS users, indicating a lower willingness to pay among the former. However, because the Android users form part of a large platform, businesses are willing to advertise through this channel and fund non-paid-for apps in exchange for the users' attention. Some of the most popular apps in Europe at the moment are free of charge.

The monetisation potential from charging for apps seems to be correlated with the price of the smartphone owned by a user: the lower the price of the device, the fewer paid apps there are (see Table 3.1 below). If each device maker had its own OS, the app developers would prioritise the OS used by consumers with a higher willingness to pay and might not develop for the other OS unless they reached a large user base.

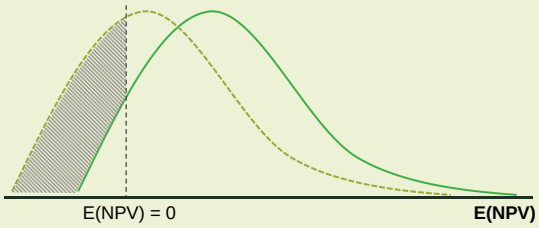
Box 3.1 Economics of app development

The decision to develop for a particular OS is driven by considerations similar to those that govern the decision of a potential new provider to enter a market. Ultimately, a firm will do so if the expected net present value (NPV) is positive.

The literature that has dealt with the app economy models profit as a function of the average profit per customer on the platform (M_p), the number of users of the platform (U_p) and the app's reach on the platform, which is a percentage of the platform users who actually use the platform (r_p).[1] Hence the expected variable profit of an app on a platform (P) is:

$$P = U_p \times M_p \times r_p$$

The figure below represents a hypothetical frequency distribution of apps according to their expected NPVs pre-entry. The pronounced skewness to the left reflects that a significant proportion of app developers can be catalogued as 'entrepreneurial', and do not rely on on- or offline businesses for the success of their app. An established online business (such as Amazon) or an offline business (such as a bank) can expect their app to be successful, and would therefore be towards the right of the distribution.



If the number of users on a platform were to reduce, the distribution of expected NPVs (the solid green line) for apps would shift to the left and the expected NPV of each app would be lower. While many apps would still be profitable to create, an increased number would now be unprofitable and would not be developed. This is shown by the shared area in the figure above.

App developers will be less keen to build apps for a smaller potential market, particularly small-scale apps with specialist or localised appeal, which would be at an increased risk of making losses. As a platform expands and the user base grows, the reverse logic applies. A virtuous circle is created, attracting more app developers into the market.

Notes: [1] Bresnahan, Orsini and Yin (2014).

[41] Mobile app monetisation dossier; Statista data based on App Annie.

Table 3.1 Android smartphone price and paid apps

Price of current phone	None	At least one
Low (€1–€250)	82%	18%
Medium (€251–€500)	74%	26%
High (€500+)	58%	42%

Base: 4,002 consumers who reported the price of their current phone.

Source: Oxera based on consumer survey.

3.3 Reduced fragmentation

App developers benefit from the wide range of devices that Android supports, given the possibility this provides to write code once and know it will reach all compatable Android devices. There is a consensus among the developers we surveyd that having multiple versions of an OS leads to delays in bringing a product to market as it requires additional code, and hence cost, at the development stage and a longer testing process. In some cases, app developers solve this problem by limiting the functionality of their product to ensure it will work on all versions.

We can't always use the latest features available in the OS because we can't assume the user will have access to those features

App developer, Spain

When asked if there were benefits to fragmentation, 15% of the app developers mentioned the access they get to older devices when users choose not to invest in a new phone. However, the vast majority of app developers (69%) raise concerns about the costs associated with fragmentation. Google addresses this by limiting the fragmentation of the Android OS through the Android compatibility commitment but still maintaining backwards compatibility.

I must write additional code to make my apps work well with the Android partners

App developer, Italy

Limited fragmentation allows products to be introduced to the market more quickly by reducing the development and the testing times. Based on the survey of app developers, testing can take between 2 days and 5 months, depending on the type of app. 27 app developers provided a breakdown that includes testing times and represents on average 24% of the entire app development process, although it varies from 4% to 70%. The majority of app developers said that it takes between 15% and 25% of the time.

The additional development time needed to adapt an app to another OS varies depending on their size, but is a significant draw on the developers' time, as can be seen in Table 3.2.

Table 3.2 Time for additional OS adaptation

% added time	% of app developers
5–10%	4%
10–20%	11%
20–30%	17%
30–40%	16%
40% +	45%
Don't know	7%

Source: Oxera based on app developer survey.

Considering the large number of Android devices, a fragmented OS market in which each device maker has its own app platform would result in additional time requirements for app developers. If some of these platforms had few users, they would not be able to reach the critical mass of applications necessary to attract app developers and users to their platform. This in turn would lead to a poorer overall user experience, with a lower average quality and lower innovation as more resources would be spent existing apps instead of creating new ones.

There are currently not enough developers to meet demand in the industry, as highlighted in a European Commission report from 2014.[42] Thus, smaller OS platforms may not be served by app developers, who would choose to focus primarily on the OSs with the largest or most profitable user bases—giving their app the greatest chance of success.

The Android ecosystem benefits also materialise through the Play Store, which is regarded as a trusted source by users and as a secure platform by app developers.

Security level is high so I feel safe when I upload my apps on Google Play Store

App developer, Germany

[42] European Commission (2014).

3.4 Virtual agglomeration

When suppliers of similar goods and services locate in the same place, the total value they create tends to increase. This is due to an increased productivity of every supplier due to the sharing of output, knowledge spillover and pooling of labour (see Box 3.2)—an effect economists refer to as agglomeration.

In the case of Android, we consider the 'virtual agglomeration' that results from the 'gathering' of software developers around a particular set of technologies. App developers who choose to use Android not only gain access to its users, but also enjoy the benefits of agglomeration through the sharing of knowledge and skills, in the same way as a university or science campus increases productivity by increasing access to knowledge.

The Android documentation is a lot better: there are good examples and help on internet, so it is easier to fix a problem in comparison to other ecosystems

App developer, Poland

79% of the app developers we surveyed recognised some sort of knowledge spillover as one of the benefits of developing on Android. Many of the coding techniques that app developers and third parties create on Android have positive externalities, as these techniques become common knowledge and are used as building blocks for further innovation.

Android has many libraries that you can use. Also, Android is always evolving, and the Google team is as well to provide the additional tools to make our life easier

App developer, Germany

To take advantage of the effects of virtual agglomeration, the Android open source is compatible with a wide range of software coding languages. This broadens the pool of individuals with different skillsets who can learn from each other and allows better matching between the market requirements and the appropriate talent, making the labour market more efficient.

Android works with Java, so I did not have to learn another language to develop for it

App developer, Italy

In a similar fashion to the agglomeration effects of urbanisation on productivity, we estimate that halving the number of app developers on the Android platform would be associated with a fall in productivity for the remaining ones of 7.4%.

Box 3.2 Economics of agglomeration

Economics seeks to explain what, how and for whom firms produce. Agglomeration economics adds the 'where'.

Firms' location decisions may have affect their returns through 'economies of agglomeration'. The relevance of these effects is well documented in the literature, although they focus on geographic proximity.

When suppliers of goods or services locate in the same place, the aggregate value-added they can create is greater than the sum of what they could create if they were located separately. Thus, productivity increases when people are surrounded by others doing similar activities. The mechanisms that allow agglomeration to yield these benefits are the sharing of output, knowledge and technological spillover, and input matching. These can be seamlessly extrapolated to the app economy.

Sharing of output: how often do people enter a shopping centre intending to buy one thing and end up buying something else? On Android, an app developer benefits from having other apps alongside its own because the consumers that others attract also see their app.

Knowledge and technological spillover: why is France famous for its food and Germany for its cars? When programming for Android, app developers can learn from one another such that the overall app quality ends up reflecting common knowledge and shared technology.

Input matching: why are there so many banks and financial analysts in London and so many designers and fashion companies in Milan? Android attracts specialised and highly skilled developers such that their talent can be easily matched to start-ups with innovative projects.

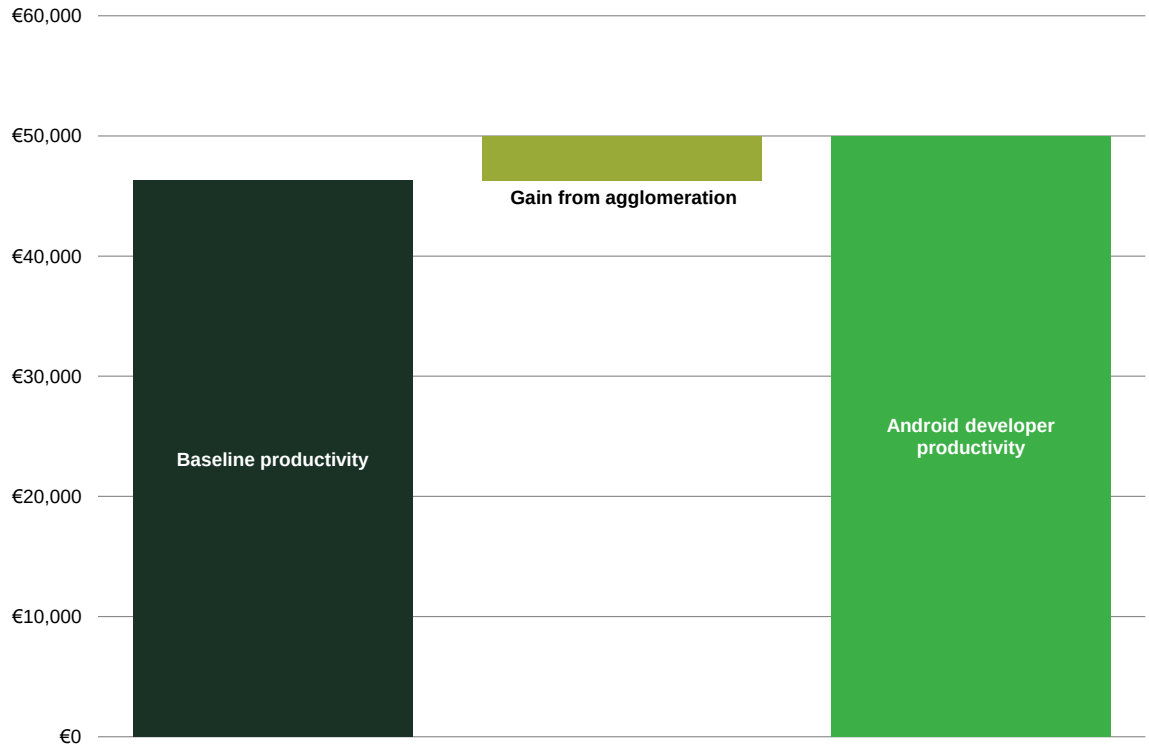
While the academic literature has not examined specifically the agglomeration of software developers around technological hubs, its importance may be implied from two empirical findings:

1. the effect of agglomeration on productivity is particularly relevant for services relative to manufacturing industries; and
2. the increase in productivity is greater when agglomeration takes place through the addition of labour via small businesses.

Source: Graham, Gibbons and Martin (2009); Rosenthal & Strange (2010); and Duraton, G. and Puga, D. (2003).

This is based on an elasticity of productivity to agglomeration of 0.148.[43] This means that the value-added of the remaining developers would fall by over €4,000 per year. Taking into account the number of developers, the total productivity loss in Europe of halving the agglomeration of developers on the Android platform would be of €3.4bn (see Figure 3.1).

Figure 3.1 Effect of agglomeration/fragmentation per developer



Source: Oxera based on progressivepolicy.org, itjobswatch.co.uk, and Melo, Graham & Noland (2008).

[43] This elasticity is based on Melo, Graham & Noland (2008). For a description of the estimation of the effect on productivity of reducing the size of Android, see Appendix 3.

4 Why do device makers choose to run Android?

The success of the Android OS is based on the collaboration of multiple parties with a common goal. The Open Handset Alliance brought together all the parties needed into a fully integrated system. Entry by new joiners has strengthened the Alliance and allowed for more knowledge to be shared through the Android open source. This new model of doing business brought down a significant barrier to entering the smartphone manufacturing market; namely, the development cost of an OS.

Android supports 24,000 devices from more than 1,300 manufacturers.[44] Many of them benefit from the royalty-free OS, which allows them to keep costs low and compete in the handset market. Companies such as Fairphone rely not only on the Android OS, but on the entire ecosystem that the OS provides to ensure that its product works 'out of the box'.

The Android value stack is already mature, so we are not very much worried about it as it is quite better than the other operating systems

Device maker, Hungary

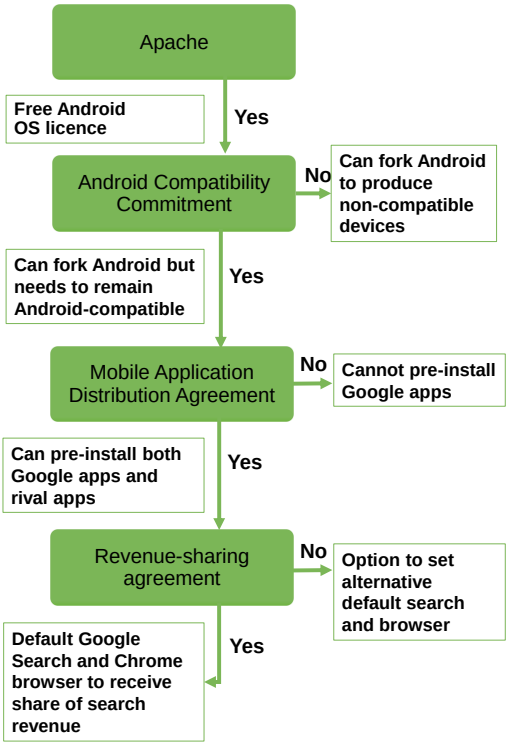
The Android business model ensures that the user experience from a bespoke or start-up device manufacturer is comparable to that of a big provider in the market. More importantly, Google allows this to happen at no charge to the device manufacturers. Indeed, the RSAs help smaller manufacturers to finance their innovations, and encourages them to produce handsets that reach as many customers as possible.

4.1 Survey of device makers

To understand the benefits that device makers receive from Android, Oxera commissioned Kantar Millward Brown to interview 10 Android device makers that are based in Europe or sell in Europe. Their products range from smartphones, tablets, wearables, and the Internet of Things to car devices, with a wide range of prices from less than €50 to more than €1,000.

The majority of device makers interviewed said that when choosing an OS, they look for one that provides them access to a large user base, enables faster development of products, reduces R&D costs, offers brand benefits, and allows them to manufacture devices at lower prices.

Figure 4.1 Google's device maker agreements



Source: Oxera, based on discussions with Google

4.2 Google's agreements with device makers

Google has up to four agreements with device makers, as illustrated in Figure 4.1.[45]

Apache licence

The Apache licence entitles device makers to customise the Android OS code according to their device characteristics. This licence is offered without royalties and can form the basis for a competing OS, as is the case of Amazon's Fire OS.

Android compatibility commitment

Device makers wishing to modify the Android code while remaining compatible with the wider Android community can sign the Android compatibility commitment (ACC) and pledge to preserve a consistent end-user experience. In return, the device makers get access to millions of apps that are made to work for their devices, as explained in Box 3.1 in section 3. The ACC gives device makers the flexibility to bring to market differentiated devices, while protecting the ecosystem from fragmentation by a proliferation of incompatible OS variants that would increase costs substantially for app developers.

[44] Pichai (2018).
[45] Based on discussions between Google and Oxera.

Mobile application distribution agreement

Smartphones need (and consumers expect) default apps, such as maps, to be pre-installed so that the devices work out of the box. Each device maker is free to choose what those apps are. device makers who wish to pre-install Google's proprietary apps such as Google Play, Google Search, Gmail or YouTube can sign the Mobile application distribution agreement (MADA).[46] MADA applications come free of charge and provide the device makers with the apps necessary to release a functioning phone without additional device maker development. This agreement does not prevent the pre-installation of other competing apps of the same type. Device manufacturers can develop proprietary applications. For example, Samsung adds to its Android-based portfolio of devices several applications, such as Galaxy apps, Samsung Connect and Samsung Pay.[47] Other device makers in Europe include bespoke apps tailored to their device. However, many device makers choose to pre-install the MADA applications because their customers regard them as valuable and provide a consistent user experience.

Revenue-sharing agreement

The fourth agreement device makers and mobile carriers can opt into, conditional on agreeing to the previous three arrangements, is the revenue sharing-agreement (RSA). This gives device makers the possibility to receive a share of the advertising revenue from searches carried out on their devices in exchange for non-exclusive prominent placement of the Google apps on the device. This allows prices to be kept lower for consumers while providing a source of revenue for manufacturers. The device manufacturers interviewed estimated that they received 1%–29% of the annual revenues from RSAs, which varied between €2m and €800m.

4.3 Reduced software development costs for new devices

Android is reducing the software development costs for manufacturers in two ways: first, it is offering the operating system royalty free through the Apache licence; and second it subsidises the development of new features offered by device makers through the revenue sharing agreements. The outcome of this collaboration is a wider range of innovative devices that enter the market faster.[48]

The main advantage of Android: it is open source, so we can customise many things

Device maker, Turkey

Moreover, Android has provided device makers with a platform that can easily sustain custom,

Box 4.1 Device integration

The personal assistant market has a number voices—Alexa, Cortana and Siri—and Google competes in this market through Google Assistant.

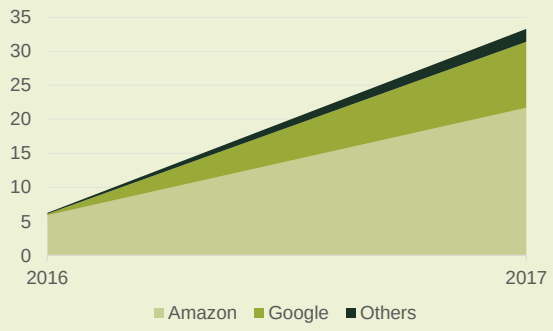
Industry analysts suggest that assistants powered through artificial intelligence (AI) will play an important role in the competitive landscape of big tech companies in the years to come. Shipments of Amazon Echo and Google Home are growing rapidly, with competition between the two hinging on software intelligence and integration. The information collected from users drives the learning curve of these AI assistants and, for this reason, integration with mobile devices is crucial in order to keep up with consumers' expectations.

As well as the open source code providing the basis for the Echo's operating system, Android has facilitated Amazon's surge in this market by enabling smartphones to communicate with third-party external devices such as Amazon Echo. Android users can download Amazon's Alexa app from the Play Store and even set Alexa as the default.[1]

Microsoft is also learning how to integrate Android into its business model and use it as a tool to improve its customer experience. In 2017 Microsoft Launcher was unveiled and made available through Google Play. This app effectively places a homescreen layer on top of Android which allows users to launch Microsoft apps that are connected to PC software.

In line with the market trend towards technological integration, Microsoft Launcher builds a bridge from an Android device to a Windows PC. In this way, the Android ecosystem has been a tool for competition. Its openness implies that users can circumvent Google's ancillary services entirely in favour of competitors, simply by downloading apps such as the Microsoft Launcher from the Play Store.

Smart speaker shipment worldwide (m)



Source: Oxera based on Statista, from Canalys.

[46] The Google proprietary apps included in MADA are: Search, Chrome, Play Store, Play Music, Play Movies, Drive, Photos, Maps, Gmail, Hangouts, and YouTube.
[47] See https://support.t-mobile.com/docs/DOC-34273
[48] See https://opensignal.com/reports/2015/08/android-fragmentation/

pre-installed software. In comparison with integrated systems, the open source Android OS allows device manufacturers to focus more on device characteristics as the base software and ecosystem of apps and services is already available.

For example, one of the device makers we interviewed explained that their devices built on the existing Android code by adding more sensor facilities that allow their customers to better monitor their personal fitness indicators.

Depending on the complexity of the devices produced, the device makers interviewed estimate that an OS would have cost them between €15,000 and €20m. In addition to the development cost, it would delay the introduction of the device to the market because an OS takes time to develop. As the Android code is evolving, the device makers can use the debugging, maintenance and upgrading available in the Android community, which has been estimated to save them up to more than 30% of their annual revenue.[49]

The open source project has benefited even those device manufacturers that have opted to depart from the Android-compatible ecosystem. Forking Android into alternative OS is an option that Amazon has taken, for example. Android has provided a base on which to build Fire OS, which has reduced costs significantly.

4.4 Access to a rich ecosystem

The importance of the ecosystem around the OS is one lesson that Android learnt from Symbian. Smartphones today represent more than just their hardware and software components; they enable access to other services through apps.

However, the creation of apps is a complex process that requires input from more than just the device maker. With Android, the device manufacturers benefit from a trustworthy and secure OS that has already built a rich ecosystem around it.

Android is approved in pretty much every country, so we don't need to waste time getting approval (…) Android developers are plentiful and easy to find; it is an affordable resource to build what you need on top of it.

Device maker, UK

Using the Android OS, the device makers also benefit from the network effects between users and app developers. Among the device manufacturers interviewed, 8 out of 10 respondents highlighted that they value joining the Android ecosystem because its brand is recognised by consumers and because there is an abundance of readily available apps compatible with their devices as soon as they are shipped.

Android is more widely accepted and cheaper to use by a larger number of users. It is much easier to program and develop apps for, it is even cheaper to post on the Android Play Store rather than the Apple App Store.

Device maker, Greece

In addition to the software component of Android, device makers can benefit from the compatible Google apps and services. For 7 out of 10 respondents, Google Play app and services enables them to provide a consistent user experience, and 6 respondents consider that it would be harder to keep their device up to date without them.

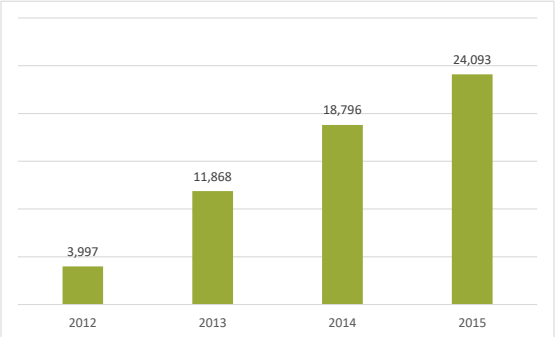
without the Google apps and services there would be a marketing impact on our business: it would be harder to advertise the product and have easy access to applications.

Device maker, Italy

4.5 Easier prototyping and faster product launch

Android has allowed technological start-ups to develop software or hardware products that are directed at smaller, more specialist segments. By granting free access to their OS, Android lowered the barriers to entry to the smartphone market significantly. As can be seen in Figure 4.2 below, between 2012 and 2015, more than 20,000 Android device models were introduced to the market worldwide. This made it possible for highly specialised products, which cater only to small niches of the market, to reach consumers.

Figure 4.2 Number of Android device models



Source: Oxera based on OpenSignal data.

[49] Based on the savings reported by device makers in the survey.

Why do device makers choose to run Android?

In 2010, GeeksPhone One, the first European-made smartphone, was launched. It focused on allowing end-users maximum customisability and ran on Android 1.6 Donut. A more recent example of a producer of highly specialised Android devices is the UK-based Bullitt Group Ltd. Bullitt manufactures phones designed for companies such as Caterpillar and Kodak. The Caterpillar-branded phone is also known as the 'rugged' phone, whereas Kodak's product is aimed at photography enthusiasts.[50] Peter Stephens, Bullitt's CEO, estimates that the niche and highly specialised smartphones accounted for about 4–5% of the smartphone market in 2016.[51]

Having access to a well-developed OS without incurring any additional costs makes it possible for these companies to concentrate purely on hardware to meet the particular demands of their niche market. As explained by the Dutch Fairphone, a producer of ethical and modular smartphones:

Using Android right from the start enabled us to really focus on some other things and getting a very good operating system without having to invest a lot of resources of time and money

Fairphone, the Netherlands[52]

This helps freeing up resources for marketing as well as research and development for hardware components. In the alternative scenario, where there is no well-established OS available, or all OS charge a licensing fee, it would have been significantly harder for these specialised companies to gain a foothold. Facing the additional costs of licensing or fully developing their own OS might not be feasible for smaller companies. This would result in the demands of the previously mentioned 4–5% specialised smartphones users not being satisfied.

A non-exhaustive snapshot of European phone manufacturers founded after 2000 and still operating (as at July 2018) shows the prevalence of Android OS among these (mostly) smaller companies. Only the Finnish Jolla also provides an in-house OS alongside its smartphones.

Table 4.1 Selection of European device makers

Company	Country	Founded	OS	Revenue (€m)
Jolla	Finland	2011	Sailfish OS	0.96 (2016)
HMD Global (Nokia)	Finland	2016	Android OS	1,800.00 (2017)
MobiWire	France	2011	Android OS	91.86 (2017)
Wiko	France	2011	Android OS	500.00 (2015)
Gigaset	Germany	2008	Android OS	293.30 (2017)
NGM	Italy	2003	Android OS	17.50 (2016)
Just5	Latvia	2008	Android OS	0.51 (2013)
myPhone	Poland	2008	Android OS	N/A
Allview	Romania	2004	Android OS	34.54 (2017)
Evolio	Romania	2007	Android OS	4.04 (2015)
E-Boda	Romania	2003	Android OS	9.22 (2017)
Myria	Romania	2006	Android OS	74.67* (2017)
Utok	Romania	2012	Android OS	42.00* (2012)
BQ	Spain	2010	Android OS	200.00 (2014)
Bullitt Group	UK	2009	Android OS	200.70 (2017)

Note: * Revenue figures for parent company.

Source: Oxera based on publicly available data

[50] The *Economist* (2016).
[51] Ibid.
[52] See https://www.youtube.com/watch?v=YVjq7r7zNCo

5 Case study: Android Auto

Having discussed the benefits that the existing Android ecosystem offers to consumers, app developers and device makers, we now consider how these benefits manifest themselves—particularly as our digital ecosystem starts to extend beyond the smartphone.

Drivers in Europe spend an average of 1–2 hours in their cars each day.[53] This compares with the average of 1.5–2 hours a day they spend browsing the Internet on smartphones.[54] While in the car, there are numerous connected services that consumers make use of, such as mapping, communications, music and information updates. Android Auto provides drivers with an easy and safe way to interact with these familiar mobile apps and services while on the road.

5.1 What is Android Auto?

At its core, Android Auto is a standard mobile app that can run on any Android smartphone. Launched in 2015, the app is designed to run on a device that has been 'docked' in a basic, in-car smartphone holder. It provides an easy-to-read, driver-centric interface directly on the smartphone screen. This interface allows users to interact with the main functions of compatible apps in a simplified way while driving.

If, however, the device is connected to the infotainment system of an Android Auto-compatible vehicle, the app is projected onto the vehicle's 'head unit' (the infotainment system's built-in display). As well as providing a larger screen for the graphical interface, using the Auto app in 'projected' mode allows the driver to interact via the vehicle's in-built hardware (e.g. the speakers, microphones and steering-wheel controls). There are already more than 500 Android Auto-compatible vehicle models and over 50 aftermarket stereos available, and the number continues to grow as Google builds partnerships with more and more vehicle makers.

Figure 5.1 Android Auto

Source: Oxera.

In 2016, Google took Android Auto a stage further when it announced that it will extend the Android OS to become an in-car platform that manufacturers can use to power their vehicles' infotainment systems, with no need for a separate smartphone. Since then, several big-name car marques, such as Audi and Volvo, have partnered with Google to include Android-powered infotainment systems in future models—though these are not yet available to consumers.

For regular Android users, these Android infotainment systems will offer a familiar experience, very similar to using the Android Auto app. However, a deeper integration with the vehicle's non-critical systems will allow Android Automotive to offer drivers a range of additional vehicle information and cockpit controls.

5.2 Continuity of apps and services with a familiar user experience

In today's digital world, consumers are accustomed to being connected, informed and entertained continuously. Since Android Auto forms part of the integrated Android ecosystem, it allows users a seamless continuation of what they were doing when they entered the vehicle. For example, Android users who regularly connect to smart devices in the home could start listening to audio using their smart speakers, before transitioning seamlessly to the car. The Android Auto-compatible music, radio or podcast app will pick up right where it left off.

Furthermore, it is not just the Google apps such as Play Music and YouTube Music that are compatible. Consumers can choose from a wide range of competing music services that integrate with Android Auto, such as Amazon Music, Spotify, TuneIn, ScoutFM and many others.

Similarly, with around two-thirds of Android users sending messages or accessing social media on their smartphone at least once per day, someone having a conversation by text message, or via a service such Facebook Messenger or WhatsApp can carry on through Android Auto. The platform provides compatible apps with text-to-audio read-outs for new messages and voice recognition for replies.

This continuity becomes increasingly important as services such as Google Assistant become increasingly prevalent. These tools improve their understanding through use, while the information they can provide and the actions they can take become more valuable when they are part of an integrated whole. For example, a driver asking Google Assistant for directions to their next appointment and informing others of their ETA will get a better result if the assistant is able to seamlessly interact with the driver's calendar and telephone contacts.

[53] Pasaoglu Kilanc et al. (2012).
[54] Ofcom (2017), p.151. Countries surveyed include France, Germany, Italy, Spain and the UK.

Many consumers also rely on smartphone apps for information and directions when on the move, with around one-third (35%) of Android users referring to navigation apps at least once per day. Android Auto supports both Google Maps and the Waze app, providing users with a seamless navigation service through a familiar and easily searchable interface.

As well as giving consumers a better experience, both businesses and society benefit from users having access to a rich and up-to-date database of destinations and routing information (as compared with the more limited and static data typically offered by an on-board or third-party navigation system).

Using better maps helps consumers to find businesses and services they need (such as food or retail outlets) when they need them. This both reduces their search costs and increases competition between those services, to the benefit of all society. In turn, businesses can promote themselves within these services, by completing their profile in tools such as 'Google My Business'.

5.3 Safety on the road

As well as seeking to provide a high-quality user experience, Android Auto is designed to maximise safety when interacting with infotainment services while driving. The user interface is tested in driving simulators to maximise ease of use and minimise driver distraction.

A recent report by AAA in the USA has shown that using a familiar interface such as Android Auto or Apple CarPlay reduces the amount of attention drivers must divert to controlling their infotainment system, as compared to using vehicle makers' own interfaces.[55] In addition to being intuitive, safety experts have recognised the benefits of this reduced need for attention while driving. A driver taking their eyes off the road for over two seconds doubles the risk of being involved in a collision.[56] This puts into perspective the significance that any reduction in driver distraction can have. Studies have found that, on average, Android Auto users take 5 seconds less to make a call, and 15 seconds less to interact with navigation tools, compared with users of car makers' own infotainment systems.[57]

5.4 Higher quality and reduced cost

Operating in a highly competitive marketplace, vehicle makers are constantly looking for ways to make their vehicles stand out to consumers. One way is to offer a seamless integration with the consumer's digital ecosystem through Android Auto. Since Google does not charge vehicle makers for integrating with Android Auto, this can be a low-cost way of providing consumers with an alternative offering, alongside the vehicles own custom systems. Making an infotainment system or third-party stereo Android Auto-compatible requires only a small amount of code to be included on the device maker's side, to integrate the display and hardware controls. All of the additional processing and data storage is undertaken by the connected smartphone.

For some consumers, the familiarity of experience offered by Android Auto will be preferable to learning to navigate the vehicle makers' custom infotainment system. Car quality scoring reports show that, in 2018, 22% of problems reported in the first 90 days of owning a new vehicle related to the infotainment system.[58]

With Android Auto, there are also significant 'economies of scale' that allow for a continued development of new features. For a vehicle manufacturer, the costs of developing and updating a high-quality, self-contained infotainment OS are spread across only those vehicles that it sells. For Google, the cost of providing the Android Auto platform can be spread across a larger number of vehicle users, while the costs of providing a wide range of quality services across the platform are spread across thousands of compatible app providers (such as Amazon, Spotify, and Facebook).

Furthermore, the development costs are minimised on Android Auto as the platform is designed to allow significant re-use of the core code that developers have already written for apps in the Android ecosystem. For vehicle makers, and for society, it can be more efficient to allow Google and these third-party app developers to create enhanced offerings that integrate with the vehicle's existing infotainment systems, while the vehicle maker focuses on its core business of engineering and design.

The benefits of this type of 'vested outsourcing'—where both parties have an interest in the success of the other—are well documented.[59] In the case of Android Auto, it is in the interest of car manufacturers for Google and the range of app developers to succeed, just as it is in Google's interest for the partner manufacturers to prosper.

5.5 Less fragmentation for developers

As is the case with smartphones, the in-vehicle infotainment system controls, display hardware and OS differ significantly between manufacturers, and even between models of the same marque. As such, with traditional, custom

[55] AAA (2018).
[56] Morris et al. (2013).
[57] Newcomb (2018).
[58] J.D. Power & Associates (2018).
[59] Vitasek and Manrodt (2012).

infotainment systems, this fragmentation poses a significant hurdle for app and service providers wishing to integrate their apps into vehicles. While there are some examples of service providers entering into partnerships with vehicle makers (e.g. Spotify with Volvo and some others) this is generally limited.

In contrast, there are already thousands of Android Auto-compatible apps widely available. As with smartphones, app developers need not worry about the hardware or infotainment system they are running on. Variations between vehicles such as the range of steering wheel controls, touchscreens, touch pads, physical buttons and dials, and speaker systems, are all handled by the Android Auto integration. App developers need only ensure their app complies with the relevant Android Auto API template to gain access to the in-car platform.

5.6 Open to Google's competitors

Android Auto provides any developer of a media or messaging app with easy access to the in-car platform. With a simple extension to its existing Android app, a developer can expose its compatible content and functionality to the Android Auto interface, albeit with some restrictions on functionality.

In order to ensure a focus on driver safety, Android Auto requires developers to adhere to strict guidelines when making their apps Android Auto-compatible. These are designed to limit distractions on the infotainment display (such as prohibiting animations), and to simplify user interactions with the app (such as promoting voice commands). To ensure compliance with these standards, Google tests all apps requesting Android Auto support against a published list of criteria before allowing an update into the Play Store.

When a user enters Android Auto mode—either through the app on their phone or by connecting their device to an Android Auto-compatible vehicle—any Android Auto-compatible app installed on the device is automatically offered via the Android Auto interface. In doing so, Android Auto facilitates increased competition between providers of services such as music streaming, messaging and voice calling in the vehicle environment.

6 Conclusions

Digital platforms, including Android, have come under close regulatory scrutiny in recent years. To assess the impact of any intervention into the evolving platform business model, it is vital to understand the sources of value and interdependencies that exist within a platform's wider ecosystem.

This report has described and, where possible, quantified the value arising from Android. We conclude by summarising how consumers and businesses across Europe are benefiting from the characteristics we observed.

6.1 Android creates social value as an economic platform

Platforms have a critical role to play in underpinning Europe's digital economy by providing a place for consumers and businesses to come together. The wider Android ecosystem—including not just the well-known mobile OS, but also the Play Store, Google's Play Services and the ever-increasing range of Android-powered smart devices—is an important example of such a platform.

A platform's success is based on entering a 'virtuous circle' of growth on both sides of the market. In the case of Android, its global reach and substantial user base provide a rich market for app developers and service providers to tap into, while the array of apps and services on offer together with broad range of compatible devices attract yet more users.

From its inception, Android was designed to foster this multisided growth, drawing lessons from the example of the now defunct Symbian mobile OS.

First, Android chose to maximise its consumer base by offering the OS to device makers free of charge. Second, by opening the platform to all developers, Android maximised the range of apps and services available to consumers. Finally, by providing a standard for the interoperability between different devices, Android maximises the variety and choice of hardware available to consumers, while maintaining the scale benefits of the wider ecosystem.

6.2 Minimising fragmentation stimulates platform growth

A further lesson Android took from the Symbian example was the risk of excessive fragmentation within the OS. With fragmentation comes compatibility issues, forcing app developers to extensively test new releases and possibly re-work code to function properly on different 'variants' of the OS. This serves to undermine the virtuous circle of platform growth, as app developers and service providers are no longer presented with a large unified market that helps them scale more easily.

To combat this, Google sought an agreement with device makers that would ensure the Android brand represents a unified OS, while allowing room for differentiation. This gives consumers more certainty over the experience they can expect from an Android device; and developers more confidence that their Android-compatible apps will run as expected on the vast majority of Android devices. The consumer benefits of competition and specialisation among device makers are maintained, without sacrificing the commercial benefits of scale.

Our surveys of consumers, app developers and device makers confirm the success of this approach. The Android users we surveyed frequently cited familiarity, price and range of apps as important factors in making their decision. Similarly, 43 (56%) of the developers we surveyed report Android's user reach as an important factor for them to successfully monetise their apps; while 8 out of 10 device makers report instant access to a broad ecosystem as a key reason for choosing to build for Android.

6.3 Android allows more consumers to get a better smartphone

With prices for Android smartphones ranging from under €100 to over €1,000, more consumers can find a device that balances the features they need with a budget they can afford. Furthermore, with Android being offered to device makers at no cost, the price of these devices is lower than it would be if the device maker had to either:

i) develop its own OS; or

ii) pay a licence fee for an alternative OS.

This price reduction leads to an increase in sales, as more consumers are able to afford a device. This 'market expansion' effect is estimated to have resulted in 21m (18%) more device sales in Europe in 2017. This, in turn, unlocks an increaed consumer benefit, as these additional users gain the benefits of smarphone ownership—amounting to around €364 per person, per year. This in turn implies that the increased device sales due to the free Android licence was worth up to €7.6bn to consumers in Europe in 2017 alone.

6.4 Competition within the Android ecosystem benefits consumers

As a free and open source OS, supported by a vibrant ecosystem, Android helps to create more choice and competition for consumers. Android provides users with access to more apps than any other ecosystem, giving consumers a 'long tail' of specialist and bespoke apps to increase their chances of finding something that meets their needs.

As an open ecosystem with features that facilitate app multi-homing, Android also helps consumers try out the services of a range of competing providers. For example, consumers can easily download several music services (such as Spotify, YouTube Music or Deezer) and control them through the device's hardware controls, lock-screen widgets and even the Google voice assistant. Similarly, a user with multiple messaging or video calling apps can receive all their notifications in one place. They do not need to decide between different messaging services. Instead, they can conveniently multi-home and benefit from the increased network effects of having many installed.

Android users also enjoy a wide choice of devices and price points. Android ensures that consumers can easily switch between competing device makers without fear of their purchased apps or content being 'locked in'. Many consumers take advantage of this, with 58% of those surveyed having switched device maker when they bought their last smartphone.

6.5 Android increases productivity and innovation

By offering developers access to a large, global user base, Android helps new and innovative apps and services reach commercial scale quickly. For some apps, such as social media, this can unlock important network effects, while for others, such as the 'long tail' of specialist apps, it maximises the opportunity to connect with users who value their particular service.

Providing a focal technology for a community of developers results in increased productivity across the board.

Android can also help device makers innovate more easily.

i) Android allows device makers to focus on hardware innovation, knowing there is a thoroughly tested and well-maintained OS and ecosystem ready to run on their new device.

ii) Device makers have the choice of entering into an RSA with Google that can be used to cross-subsidise the new device development, allowing the device makers to keep their price attractive to consumers.

iii) Lastly, the device makers have the choice of forking Android, using the open source code as a basis for a completely new OS. Many smart devices, such as Amazon Fire TV and Echo speakers, run on modified versions of Android. Although as Android forks, they sit outside the Android ecosystem, consumers benefit from both the innovation and competitive pressure these device makers bring.

Appendices

A1 Principles of platform economics

While multi-sided markets are not new, the Internet has rescaled them to an unprecedented level. Traditional economics theory, policy and anticompetitive tools, in particular, are being hard pressed in dealing with the issues governing economic platforms. Because of the complexity around them and their relevance for society, many competition authorities place digital markets, which are mostly structured as multi-sided platforms, high in their agendas.

This appendix sets out the principles of multi-sided platforms. Notably, the theoretical literature on this subject is not yet mature. Seminal contributions, such as that of Rochet & Tirole in 2003 and the following years, have catalysed further articles in the field. However, the fast pace of publications suggests that there is still space for the theory to catch up in explaining the phenomena underpinning multi-sided markets.

Economists have put forward many definitions of what a multi-sided platform is. Most have in common the recognition that the platform must attract two or more different types of user, and that the benefits for the individuals on one side of the platform must depend on the number of individuals joining on the other side.

First and foremost, platforms are facilitators of interactions between two or more types of user. They solve a problem for economic agents by reducing search costs and working as conduits. For this benefit to be significant, platforms require a critical mass of users on both sides. For instance, a price comparison website (PCW) that facilitates the interaction between travellers and hotels would not be adding much value to travellers if it offered access to only a handful of hotels in a city where there are thousands of them. Similarly, if only a few individuals used the PCW to search for hotels, the hotels would be unlikely to find it worthwhile advertising through the platform. Thus, when it comes to multi-sided platforms, the social benefits they create depend to a significant extent on their size.

Rochet & Tirole (2005) define a market as two-sided if the volume of transactions that take place through it varies when the price allocation for each user side changes while the total price level (i.e. the sum of the prices charged on each side) does not change. Consider a platform that intermediates transactions between two types of users: User type 1 and User type 2. If the platform charges per-transaction fees of f_1 and f_2 to each type of user respectively, then the authors' definition implies that, if the volume of transactions varies with f_1 while the sum of f_1 and f_2 remains constant, then two-sidedness exists in an economic sense. If, on the contrary, the volume of transactions through the platform depends exclusively on the total price level, then the market is said to be one-sided.

A corollary of the above definition is that, for a market to be two-sided, the Coase theorem must fail. This is because according to the Coase theorem, a Pareto-efficient outcome will be reached (i.e. the volume of transactions will vary to reach a social optimum) regardless of the initial price allocation, and the ultimate benefits to all parties will depend only on the total price level, as long as there are no transaction costs or asymmetric information, and property rights are well defined. This theorem clashes with the property of a two-sided market, in that the price structure is relevant in determining the number of transactions that take place through the platform.

A second implication of this definition is that a key component for the success of a platform is the correct calibration of prices for each user type. This is an additional condition to the generally accepted notion that, for platforms to succeed, both sides need to be on board. Indeed, only if all necessary user types join can the platform be sustained: a game console can thrive only if it has enough gamers to be attractive to developers and enough games to be attractive to gamers; a newspaper's success depends on having sufficient readers to attract advertisers, enough advertisers to be able to pay writers, and enough writers to attract readers; a payment card will be successful only if there are enough customers using the cards to incentivise retailers to accept them, and if enough retailers accept them such that users have an incentive to pay by card.

From the above, it can be concluded that the number of users present on one side of the platform is a function of the price charged by the platform to those users and the number of users of the other side. It is straightforward to see that there is a second-order effect when modifying the price to one side: as the price for one category of users changes, the first-order effect is a change in the number of users of that category, but since this number affects the benefit that the other category of users can obtain from using the platform, their number will be indirectly affected. By the same argument, there will be subsequent ramifications,[60] known as 'indirect network effects'.

Indirect network effects introduce a complexity in pricing decisions for multi-sided platforms that is not present in one-sided markets. As a rule of thumb, platforms should offer relatively more attractive commercial terms (i.e. charge more cheaply) to the user type with the highest elasticity of demand. This is

[60] Evans et al. (2011).

because, for any given price reduction, the more elastic side will be more responsive and therefore trigger the highest indirect network effects. Furthermore, Rochet & Tirole (2005) mark as a key insight that, in the case of platforms, the marginal cost of a transaction should be adapted to account for the extra revenue that can be earned from the other user side (assuming positive network effects). This offsetting effect implies that a platform will have a higher incentive to reduce the price for one side as the network effect of the other side is higher.

There are several determinants to the structure of a multi-sided platform market. Evans & Schmalensee (2005) identify that the size and concentration of platforms in an industry will depend on the strength of the indirect network effects, scale economies, congestion, the prevalence of multi-homing and platform differentiation. We consider each in turn.

Indirect network effects take place when 'individuals care about the decisions of others because of their effects on the incentive for the provision of complementary products'.[61] Indeed, a particular user of a platform only cares about similar-type users joining insofar as it incentivises the other type of users to join. Scale economies can also play an important role in the structure of a market with multi-sided platforms. If the fixed-to-variable cost ratio is large, the industry is likely to be charachterised by a few, large platforms.

Congestion may limit a platform's potential to growth, and set the conditions for niche platforms to emerge. In the case of mobile app developers, for example, it is increasingly costly to be visible to consumers, given the number of rivals that compete for their attention. Developers entering the market with resources that allow them to single-home only face a trade-off between the higher user base of the large platforms (e.g. Apple's App Store and Google Play) and the greater visibility in the smaller ones (e.g. Aptoide). However, in general, online platforms are better placed to solve congestion problems because of the possibility of using software tools that improve the intermediation services. Other platforms, such as shopping malls or heterosexual nightclubs, often find congestion to be the main limitation to their growth because the difficulty for users to connect increases with the number of users.

Another important factor for the structure and size of platform industries is the prevalence of multi-homing by users. Multi-homing takes place when users use more than one platform. Albeit seemingly straightforward, this adds a key layer of complexity to the analysis, as it drives the level of competition in the market, the bargaining power of each user side and several other market outcomes. The decision of whether to multi-home depends on several considerations. Some platforms charge membership fees which may discourage using more than one platform. This is the case of over-the-top media platforms such as Netflix and Amazon Prime, which charge subscription fees. Similarly, there are industries where platform-specific investment is required; examples include mobile OS, for which app developers must write programs that are platform-specific, and game consoles. In other cases, multi-homing is made unnecessary because users on the other side already multi-home. For example, most hotels use more than one PCW, making it unnecessary for consumers to use more than one PCW to access most of the hotel offerings in a particular area.

Finally, platform differentiation is a countervailing factor that could limit the growth of platforms and market concentration. This element is particularly relevant when consumers have heterogeneous preferences. For example, social media platforms, albeit large, exhibit some differentiation that allows for competition in the market. Instagram, for instance, is more widely used by young people than LinkedIn, which is regarded as a social networking tool for professionals. Likewise, some taxi apps differentiate by offering extra comfort or security, while others apply a low-cost approach.

The elements discussed above jointly set out the conditions that explain what the equilibrium should look like in an industry with multi-sided platforms. For example, in a market with strong indirect network effects and economies of scale, limited congestion, no multi-homing and no differentiation, it is likely for platforms to compete 'for the market' as opposed to 'in the market'. In this setting, first-mover advantages would be key because the first platform to reach a critical mass is likely to obtain a monopoly.

However, what the theory predicts is not always reflected in market realities. Further complexities may alter the balance of competition between platforms. For example, the bundling of intermediation services to other goods or services can facilitate competition in the market, as it would act in a similar fashion to product differentiation. Similarly, contractual agreements of exclusivity, most-favoured-nation clauses, price maintenance contracts and other commercial agreements can play a pivotal role in determining where the balance is ultimately struck.

[61] Church, Gandal and Krause (2008).

A2 Market expansion analysis

Below we set out methodology used for the market expansion analysis presented in Figure 2.5 of the main report. To confirm the robustness of this methodology under varied assumptions, Oxera conducted scenario tests (see section A2.2).

A2.1 Baseline methodology

As shown in section 2 of the main report, offering Android free of charge significantly increased the number of Android smartphone sales in Europe compared to a counterfactual scenario in which Android was offered to device makers at a licence cost of US$25. To estimate the likely change in demand if the price of Android smartphones increased by this licence cost compared to the actual yearly average price of Android phones, the analysis uses yearly sales of Android smartphones in Europe and an assumption on the PED for smartphones. This demand effect can be interpreted as the market expansion resulting from Android OS being offered free of charge compared to the counterfactual sales seen under this licence cost.

The analysis is based on the Worldwide Quarterly Mobile Phone Tracker for the years 2008–17, published by International Data Corporation (IDC). The dataset contains both the number of smartphones shipped in a certain quarter and their total value. The analysis presented here is based on the geographies Western Europe[62] and Central and Eastern Europe (CEE),[63] which could be distinguished in the IDC data. Russia has been excluded to allow for a geographic scope that reflects the European Economic Area (EEA) as closely as possible. However, according to the description by IDC, non-EEA countries such as Ukraine or Kazakhstan are also part of the CEE category,[64] but these could not be distinguished separately in the data. The countries for which a separate market expansion estimate is presented in section 2 can be distinguished in the data. The remaining European countries included in the analysis at the Europe level are not distinguishable and are categorised in the data under 'rest of CEE'.

In Figure 2.5 above the European smartphone market seems to have declined since 2015. According to IDC, further growth coming from an increase in market penetration is expected to come mostly from outside of Europe. Nevertheless, innovations such as 5G, which the first smartphones will be equipped with in the second half of 2019, are expected to be a source of future growth, with smartphone sales in Europe forecast to rise again in 2019.[65]

The expansion effect was calculated based on the of sales of Android smartphones alone. The average price level at which Android phones were sold was calculated using data on the total value of Android smartphones sold divided by the total shipments of Android smartphones in a year. To understand the development of the other smartphone OS that alongside Android phones constitute the whole market of smartphone sales, information on the phone's features provided in the dataset was used to distinguish between iOS, Symbian, RIM (Blackberry), Microsoft, Bada and all others. For 2008 and 2009, the data allows for a distinction only between Android, iOS, RIM and 'Others'. To estimate Symbian's and Microsoft's share in 'Others', the same share as in 2010 was assumed.[66]

If Google had offered Android at a licence fee charged to device makers for each device on which Android was installed, instead of monetising the costs of the development of the ecosystem through advertising revenues, the licence fee would have been US$25 in a low-cost scenario. This estimate is taken from the minimum licence fee that Microsoft currently charges for Windows 10. This is a conservative estimate—see section A2.2, which discusses the scenario test of an OS licence cost of US$45.

As explained in section 2, strong downstream competition among device makers would have led them to pass on the full cost increase due to the licence charge to their customers. This means that smartphone prices would have been higher by the amount of the licence fee if Google had decided to charge for the OS. As discussed, compared to the current situation in which device makers actually receive revenues from the RSAs, the actual 'costs' to device makers would be even higher if Google were unable to monetise its programming costs through advertising and if it were therefore unable to offer such RSAs.

An estimate of -1.77 PED was assumed, taken from Zhu, Liu and Chintagunta (2015). This represents the average PED for handsets across all smartphones. The authors use data on the US mobile phone market

[62] In the IDC data Western Europe includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK.
[63] In the IDC data CEE includes the Czech Republic, Poland, Russia and countries grouped under 'rest of CEE'. Russia has been excluded from the analysis.
[64] IDC (2018b), accessed 31 August 2018.
[65] IDC (2018c).
[66] The first phone running on Bada only became available in 2010. From this year onwards, Bada phones can be distinguished in the data. The respective share of Symbian and Microsoft phones of the total number of phones in the categories Symbian, Microsoft and Others in 2010 has therefore been taken as the respective proxy of Symbian's and Microsoft's share of the 'Others' category in 2008 and 2009.

from the years 2007 to 2008. PED is a measure of how demand varies with a change in price, and is defined as the percentage change in quantity demanded in response to a 1% change in price:

$$PED = \frac{dQ/Q}{dP/P}$$

Thus, with a -1.77 PED, if the price rose by 1%, demand would fall by 1.77%. By this estimate, the demand for smartphones is therefore elastic, as the relative demand response is stronger than the relative change in price. This is to be expected as smartphones are non-essential for living and can be considered luxury goods. Table A2.1 shows PED estimates for smartphone demand found in the literature. All presented estimates are based on the US market and serve as a proxy for the PED in Europe as estimates for Europe were not available.

Table A2.1 Estimates of price elasticity of demand for smartphones from the literature

Smartphone model(s)	Price elasticity estimate	Geographic market	Methodology	Timeframe	Source
Average across all smartphones	-1.77	USA	Using actual subscription data	2007–08	[1]
iPhone	-3.46				
By price (US$):		USA	Using a survey in which the participant is asked to choose between mobile phone service plans	2010	[2]
1,600	-17.00				
1,400	-7.50				
1,200	-6.50				
1,000	-5.34				
800	-4.27				
600	-3.35				
400	-2.35				
200	-1.34				
0	-0.39				
Price semi-elasticity for a US$10 price increase:		USA	Using actual subscription data	2013	[3]
Atrix HD	-6.47%				
Galaxy S III	-6.44%				
iPhone 4	-6.40%				
iPhone 4s	-6.35%				
iPhone 5	-6.18%				

Source: [1] Zhu, Liu and Chintagunta (2015); [2] Dippon (2011); [3] Fan & Yang (2016).

The overview shows that the estimate used the analysis is comparable to other estimates in the literature. In particular, the chosen -1.77 lies between the PED estimates of -2.35 and -1.34 for the price levels US$400 and US$200 (Dippon, 2011). The average price in Europe for Android phones was US$290 in 2017, and hence lies between these two price levels. Fan and Yang (2016) estimate the semi-price elasticity for five smartphone models. They estimate that demand for an iPhone 5 goes down by 6.18% if the price goes up by US$10 from a price of US$199.[67] This corresponds to a PED of -1.23, which is similar to Dippon's (2011) estimate at a US$200 price level. Zhu, Liu and Chintagunta (2015) estimate a PED of -3.46 for the iPhone, which means that demand is significantly more elastic for the iPhone than the average smartphone. This is expected, as Apple's smartphones tend to be sold at the upper end of the price range.

Using the IDC data and the discussed PED assumption, for each time t, the demand effect (dQ) from a price rise by the assumed licence cost is calculated as follows:

$$dQ_t = PED \times \frac{Licence\ cost\ of\ OS_t}{Average\ selling\ price\ of\ Android\ phones_t} \times Actual\ sales\ of\ Android\ phones_t$$

The demand effect is negative and represents the number of Android smartphones that would not have been sold if the price of those phones were higher by the amount of the licence fee.

[67] Fan and Yang (2016).

Both *Cost of OS* (reflecting the price change dP) and *Average selling price of Android phones* (reflecting the price level P) are in current prices at time t. That is, the US$25 has been assumed as the cost in 2017 and for all years before, and the cost has been downrated by inflation using the US consumer price index from the World Bank. This means that, in 2008, a cost of US$21.96 was assumed.

Using this approach, Oxera estimates that 21m extra Android smartphones were sold in Europe in 2017 due to the royalty-free Android OS licence.

A2.2 Scenario tests

Oxera undertook scenario tests using two sets of assumptions with respect to the licence cost and three sets of assumptions with respect to PED. Under the scenarios, it is estimated that 13–52% extra Android phones were sold in Europe in 2017 due to the Android OS licence being free of charge. This compared to the counterfactual number of Android phones that would have been sold under the respective PED and cost assumptions.

Microsoft offers its Windows 10 licence at a price range between US$25 and US$101, with licences for more complex computers being more expensive. For instance, the licence fee for the Intel Atom notebook 14.1' screen with a maximum RAM of 4GB or the Celeron 2-in-1 tablet varies between US$25 and US$45, depending on the size of storage. The advanced fee for a Core i7 with more than 16GB RAM is US$101.[68]

From this information, it is unclear whether the different licence fees charged by Microsoft for different computer types are due to differences in cost—i.e. to what extent they reflect that producing an OS for tablets and small notebooks may be cheaper than one that is suited to high-end computers—or whether the differences in fees are mainly due to price discrimination—i.e. Microsoft as a quasi-monopoly for computer OS could be charging higher prices for licences for products where the willingness to pay is generally higher. Considering the second point, US$25 possibly reflects a lower bound for what a licence for a mobile OS would cost.

Figure A2.1 and Table A2.2 below summarises the expansion effect for the six scenarios for 2017, under two cost assumptions:

- a low-cost scenario with licence costs of US$25 in 2017 (as in the base case analysis);
- high-cost scenario of US$45, based on the second-lowest licence fee that Microsoft currently charges for Windows 10, and which, among others, applies to a 2-in-1 tablet with storage greater than 32GB.

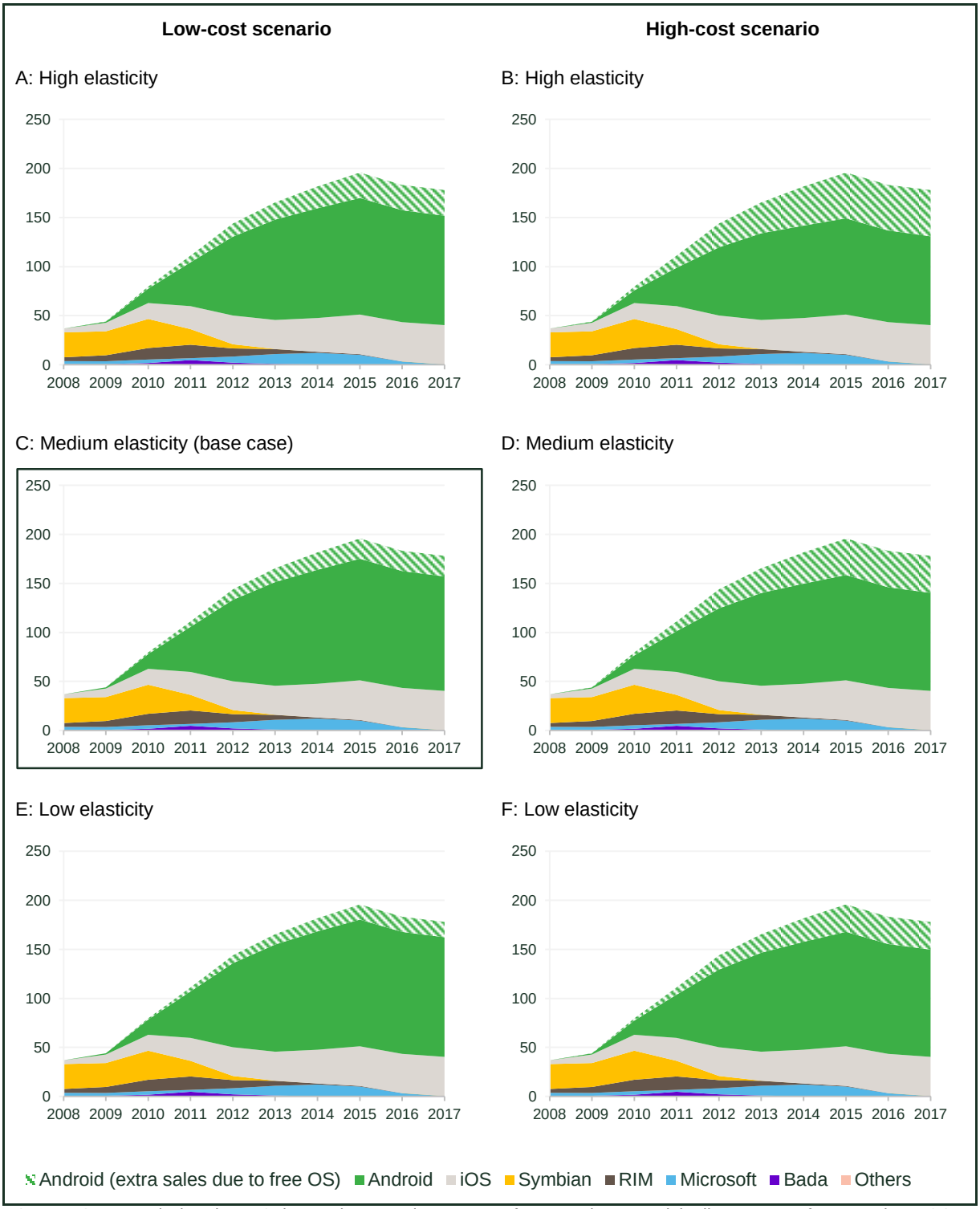
If the cost of an OS licence were US$ 45 and using the same PED assumption of -1.77 as in the base case, then, in 2017 alone, 38m extra Android smartphones would have been sold in Europe due to Google offering Android free of charge. This is nearly twice the effect compared to the scenario in which the licence cost was US$ 25.

Oxera also tested three PED assumptions, in combination with the low- and high-cost assumptions: 1.77 was taken as a medium PED assumption and the results were tested for the case that the PED was 25% more elastic (i.e. a high-elasticity scenario with a PED of -2.21) or 25% more inelastic (i.e. a low-elasticity scenario with a PED of -1.33. Under both sensitivities, demand is still assumed to be elastic.

These figures are very close to the PED estimates by Dippon (2011) for the price levels US$400 and US$200: -2.35 and -1.34 respectively. Given that the average price for Android phones in Europe was US$290 in 2017, the two elasticity sensitivities can be interpreted as the elasticity levels corresponding to a price roughly US$100 higher or lower than the average price in 2017. As a comparison, from 2008 to 2017, the average price of Android smartphones sold in Europe went down by US$190 from US$480 so that the difference in PED assumptions reflects about half the price change that occurred within this time period.Even under the most conservative set of assumptions—i.e. the scenario assuming low costs and low elasticity—we can still see a significant expansion effect.

[68] Bright (2018).

Figure A2.1 Scenario tests on cost and elasticity assumptions



Source: Oxera analysis using IDC data and assumptions on PED for smartphones and the licence cost of a smartphone OS.

Table A2.2 Expansion effect in 2017 under each scenario

Low-cost scenario (assumption: US$25)	High-cost scenario (assumption: US$45)
A: low-cost, high elasticity	**B: high-cost, high elasticity**
PED assumption: -2.21	PED assumption: -2.21
Extra handsets sold: 26.23m	Extra handsets sold: 47.21m
% expansion effect: 23.53	% expansion effect: 52.17
C: low-cost, medium elasticity (base case)	**D: high-cost, medium elasticity**
PED assumption: -1.77	PED assumption: -1.77
Extra handsets sold: 20.98	Extra handsets sold: 37.77
% expansion effect: 17.98	% expansion effect: 37.79
E: low-cost, low elasticity	**F: high-cost, low elasticity**
PED assumption: -1.33	PED assumption: -1.33
Extra handsets sold: 15.74	Extra handsets sold: 28.33
% expansion effect: 12.90	% expansion effect: 25.90

Source: Oxera analysis using IDC data and assumptions on PED for smartphones and the licence cost of a smartphone OS.

A3 Assessing virtual agglomeration effects

The methodology set out below was used to construct Figure 3.1, which shows how a 50% reduction in the number of jobs in the app market in Europe (i.e. a reduction in agglomeration) affects average productivity.

A3.1 Virtual agglomeration measures

As explained in section 3, virtual agglomeration refers to the strategic positioning of economic agents around a particular technological hub. In the case of Android, the OS attracts an agglomeration of app developers. To quantify the extent of this agglomeration, two alternatives stood out.

Option 1: using the number of apps as a proxy for the number of app developers;

Option 2: using the number of app economy jobs as a proxy for the number of app developers.

Option 1 has the crucial flaw of assuming a relatively constant ratio of app developers to apps, but this is not necessarily the case. Indeed, precisely because of changes of productivity over time, fewer app developers may be needed to develop new apps. Similarly, there is significant variation regarding the number of working hours required for some apps relative to others.

Using Option 2 is not free of problems either. This metric spans a wider range of individuals than those for whom we are estimating productivity. However, we expect the fluctuations in total app economy jobs in Europe to have a high correlation with those in the number of app developers agglomerated around Android. This is because the two variables have similar drivers: the level of competition in the app market, the expected returns on apps, labour costs, etc. For this reason, we consider that Option 2 is a closer proxy for the number of app developers programming for Android in Europe.

Information on the total number of app economy jobs was taken from reports by the Progressive Policy Institute. The count in its reports includes 'core' app economy jobs, covering app developers, software engineers and other directly related activities; 'indirect' app economy jobs, covering non-IT activities that support apps commercially; and 'spillover' jobs, covering external services provided to developers.[69]

A3.2 Productivity measures

In theory, there are many ways to estimate productivity. In a guide to quantifying the impacts of agglomeration, Graham (2018) suggests that, for labour productivity, assuming that workers are paid the value of their marginal product is sufficient to be able to use wages as an adequate measure.

While the use of wages simplifies the methodology, there is a challenge in selecting the appropriate wage. Theoretically, free movement of workers across EU countries should make real wages converge. However, this is not necessarily the case, and the observable wages for app developers of Android may vary from country to country, even in Europe.

Owing to data consistency, we have used the reported wage for Android app developers in the UK as a proxy for productivity.[70]

A3.3 Estimating the effect of agglomeration on productivity for Android app developers

The exercise underlying Figure 3.1 consists in altering the agglomeration measure described above to the counterfactual associated with an alternative scenario of interest. For the purposes here, we are interested in the effect of halving Android take-up. This is roughly consistent with modifying the current mobile OS market structure to have three big providers: iOS and two equal-sized providers, each with half the actual size of Android. This counterfactual is relevant if one considers the possibility of one big device maker, such as Samsung, switching to a model similar to that of Apple.

An appropriate elasticity measure is then needed to capture the sensitivity of productivity to changes in agglomeration. In this case, we have applied the elasticity estimated by Melo, Graham and Noland (2008) for services.[71] The authors estimate the mean elasticity across a meta-sample of elasticity measures from the literature. They then disaggregate it according to the industry group to which they belong. Ideally, an elasticity for virtual services would have been provided, but this has not been considered by the academic literature yet. The elasticity found by the authors for services is 0.148.

[69] Mandel and Long (2017).
[70] ITJobsWatch, https://www.itjobswatch.co.uk/jobs/uk/mobile%20developer.do
[71] Melo, Graham and Noland (2008), Table 2.

The formula for an elasticity is as follows:

$$\epsilon = \frac{\Delta\% \, productivity}{\Delta\% \, agglomeration} * \frac{agglomeration}{productivity}$$

Where ϵ is the elasticity of productivity to agglomeration and $\Delta\%$ represents the percentage change of the variable that it accompanies.

From this formula, it is possible to express the percentage change in productivity as:

$$\Delta\% \, productivity = \epsilon * \Delta\% \, agglomeration * \frac{productivity}{agglomeration}$$

Applying the formula above to the data in Table A3.1 with an elasticity of 0.148 yields the results observed in the last column of the table (once converting the percentage changes from factual to counterfactual to levels).

Table A3.1 Summary input and results of virtual agglomeration effect on productivity

	App economy jobs (Europe Android) ('000)	Counterfactual app economy jobs (Europe Android) ('000)	Factual productivity (£)	Counterfactual productivity (£)
2016	1,223	612	45,000	41,670
2017	1,422	711	45,000	41,670
2018	1,666	833	50,000	46,300

Note: Wage data in £ has been left in the original currency in the table, but converted to € for the main report.

Source: Oxera based on data from progressivepolicy.org and itjobswatch.co.uk

A4 Consumer survey approach and analysis

To understand who is using Android in Europe, Oxera surveyed 6,000 smartphone users online in collaboration with the Kantar Media from 2 to 17 August 2018. The survey covered four countries: France, Germany, Romania and Finland, with 1,500 respondents from each country. A weight adjustment for age group and gender has been applied to the statistics presented in this report in order to represent more accurately each country's population. The survey sampled the following proportions of users of OS: 72% Android, 17% iOS, 4% Windows OS and 7% other OS.

A4.1 What influences smartphone choice?

The survey asked about the importance of several factors that influence consumers' decisions when buying a smartphone. Android consumers' views on each of these factors are summarised in Table A4.1.

Table A4.1 Factors that influence smartphone choice, from 0 (not important) to 10 (very important) (%)

	Score 8–10	Score 5–7	Score 0–4
Price	76	21	4
Technical specs	72	22	5
Privacy and data protection	72	22	5
Operating system	71	24	5
Security and updates	71	24	5
Quality of camera	70	25	6
Familiar user experience	57	33	10
Availability of particular apps I like	55	32	13
Compatibility with previous smartphone, so I can easily transfer my content, apps and data	53	30	17
Compatibility with other devices I own so I can share my content, apps and data	52	32	16
Brand and design	51	34	15
Ability to personalise my phone	46	35	19
Compatibility with devices of friends and family	36	36	28

Source: Oxera based on consumer survey.

A4.2 Clustering analysis

The following sets out the methodology, sensitivity analysis and additional results of the profiling analysis undertaken to classify the consumers into four groups as presented in section 2. The clustering analysis focuses on Android users only (4,347 observations reweighted to represent 4,344 users).

Clustering analysis was used to group users as well as apps. The clustering of apps uses the inverted dataset and follows the same steps. The dataset comprises answers to the question: 'Thinking about a typical day, please indicate how much you use your smartphone for each of the following…'. The respondent was then shown a list of 18 app types: Internet searches, online shopping, reading free news and content, social networking, messaging apps, reading emails, taking or sharing photos and videos, streaming free music and video content, streaming paid/subscription music and videos content, playing games, educational purposes, business purposes, managing utilities and banking, navigation, looking for recommendations, fitness and health tracking, reading subscription content and controlling smart-devices. They were then asked to select between the choices: 1 'I do this many times a day', 2 'I do this several times a day', 3 'I do this once a day', 4 'I do this less than once a day' and 5 'I don't ever do this'.

To perform agglomerative hierarchical clustering analysis on this data, it was assumed that the distance between each category of answer is the same. The first step was to calculate the dissimilarity of the observation sets with a distance matrix using the Euclidian distance metric. Then, to calculate the dissimilarity between clusters of observations, the ward.D2 linkage criterion that minimises the total within-cluster variance is applied. After inspection of the resulting dendograms, four groups of consumers and three groups of questions were identified.[72] Based on this classification of the data, the four consumer clusters were as follows.

[72] The terms 'group' and 'cluster' are used interchangeably.

Cluster 1 (heavy users of advanced functionality): members are heavy users of smartphones and on average they report using 18 types of apps multiple times a day.

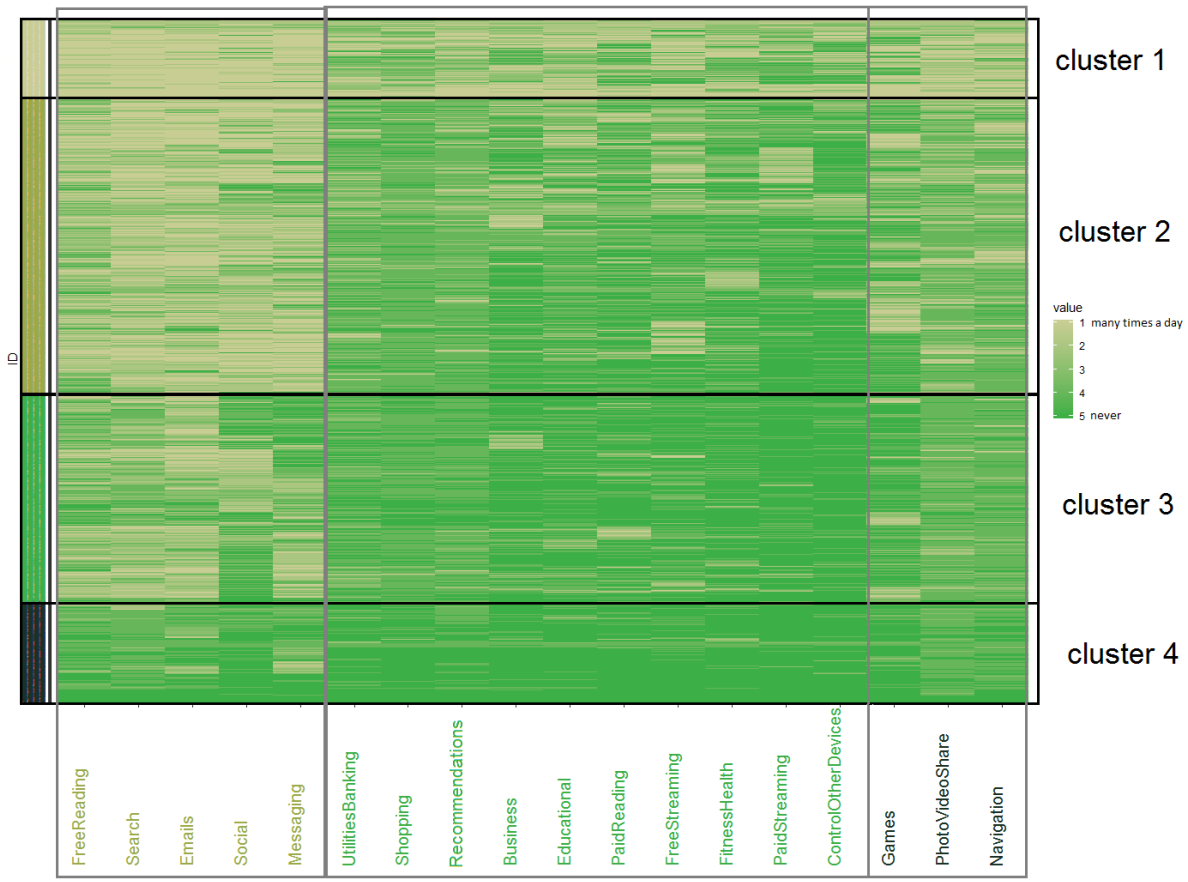
Cluster 2 (heavy users of basic functionality): members are medium-heavy users of smartphones as they report regularly using the free reading, Internet searches, emails, social networking and messaging apps and less frequently the others.

Cluster 3 (light users of basic functionality): members are medium-light users of smartphones who on average use the same types of app as users in cluster 2 but less frequently.

Cluster 4 (light users): members are light users of email and messaging apps and on average report rarely/never using the other types of app.

Figure A4.1 provides a visual representation of the clustered data.

Figure A4.1 Android user clusters based on app usage



A4.3 Sensitivity analysis

Sensitivity analysis on the method used to calculate the distance matrix was performed with the maximum, Manhattan and Canberra methods. However, the resulting clusters did not point to a sensible classification of users based on the apps used, and so the Euclidian method is preferred.

Oxera conducted a series of robustness checks on the clustering analysis using different linkage criteria. The ward.D, complete, average, and mcquitty linkage criteria yield similar results, with a high overlap between the clusters identified. The median and the centroid linkage criteria were considered not to be appropriate for the type of data used, as they place less emphasis on the similarity of the observations inside a cluster.

Oxera also performed the same clustering analysis using the k-means method. The optimal number of user groups was between 4 and 5. The choice of 4 groups based on this method resulted in a more even distribution of users that report lower usage of all types of apps. Nevertheless, the overall patterns of app usage among the groups was similar to the hierarchical clustering method.

A4.4 Results

The four clusters are described in more detail below, based on the respondents' characteristics and survey responses. As can be seen in Table A4.2, the clusters have different sizes and there is no a priori reason to expect them to be equal. The percentage of French, German, Romanian and Finnish users varies across clusters. The high share of Romanians in clusters 1 and 2 and low share in clusters 3 and 4 appear to be different from the share for the other countries. This may have been driven by a sample selection effect in the survey, leading to users with active usage of smartphones being more motivated to respond to the survey. An alternative explanation could be that there is a selection effect at the level of smartphone users in Romania, who are more likely to purchase a phone only if they intend to use it.

Table A4.2 Country and cluster membership

	France	Germany	Romania	Finland	Cluster (% of sample)
Cluster 1	9%	5%	26%	5%	12%
Cluster 2	35%	34%	55%	46%	43%
Cluster 3	35%	39%	15%	34%	30%
Cluster 4	21%	22%	4%	15%	15%
Total	100%	100%	100%	100%	100%

Source: Oxera based on consumer survey.

The first two clusters have a higher proportion of users under the age of 35 and a small proportion of users over the age of 64. The reverse holds for clusters 3 and 4.

Table A4.3 Age and cluster membership

	16–24	25–34	35–44	44–54	55–64	More than 64	Total
Cluster 1	18%	29%	26%	10%	10%	6%	100%
Cluster 2	14%	23%	19%	18%	14%	12%	100%
Cluster 3	4%	9%	16%	21%	21%	29%	100%
Cluster 4	2%	6%	8%	19%	23%	41%	100%

Source: Oxera based on consumer survey.

The price of a phone also varies between clusters. Cluster 1 members have more expensive phones, and cluster 4 members have less expensive phones. However, the percentage of smartphone users with phones that cost under €250 represents a large proportion of each cluster.

Table A4.4 Price of current phone and cluster

	Less than €250	€250–€500	More than €500	Don't know	Total
Cluster 1	45%	34%	19%	2%	100%
Cluster 2	49%	32%	13%	6%	100%
Cluster 3	56%	25%	11%	9%	100%
Cluster 4	65%	14%	5%	16%	100%

Source: Oxera based on consumer survey.

The switching patterns across all clusters are similar and highlight that a large number of Android uses switched device makers. The statistics in the table below are based only on those smartphone users who have reported the brand of their phone.

Table A4.5 Cluster membership and switching brands pattern

	Switched device maker	Same device maker
Cluster 1	59%	41%
Cluster 2	58%	42%
Cluster 3	57%	43%
Cluster 4	61%	39%

Source: Oxera based on consumer survey.

The table below highlights the difference in app usage and total number of apps between the first three clusters and cluster 4.

Table A4.6 Average number of apps

	Apps used frequently	Total apps on the phone
Cluster 1	8	28
Cluster 2	8	30
Cluster 3	6	27
Cluster 4	4	18

Source: Oxera based on consumer survey.

A very small percentage of people in cluster 1 do not know how to install or delete apps, while this percentage increases for the users in cluster 4 (see Table A4.7).

Table A4.7 Knowledge of how to install and delete apps

	Install app		Delete app	
	Know	Do not know	Know	Do not know
Cluster 1	97%	3%	97%	3%
Cluster 2	96%	4%	95%	5%
Cluster 3	91%	9%	90%	10%
Cluster 4	76%	24%	76%	24%

Source: Oxera based on consumer survey.

The clusters of users identified also differ in terms of how many paid apps they own. As such, the monetisation potential through paid apps relative to the number of total apps on the smartphone shows that users in clusters 2 and 3 benefit more from access to free apps on the Android platform (Table A4.8).

Table A4.8 Cluster membership and paid apps

	No paid apps	At least one paid app
Cluster 1	58%	42%
Cluster 2	74%	26%
Cluster 3	84%	16%
Cluster 4	90%	10%

Source: Oxera based on consumer survey. Business survey approach and analysis.

To understand the benefits that app developers and device manufacturers receive from the Android platform, Oxera commissioned Kantar Millward Brown to conduct semi-structured telephone interviews with 75 Android app developers across Europe (43 full-time employed developers and 32 contractors), and 10 devices manufacturers (8 based in Europe and 2 that sell their products in Europe) that use the Android OS. The surveys took place during July and August 2018.

A4.5 App developers' survey

Survey description

The app developers sample contained small and large companies from 9 countries across Europe (Table A4.9). The respondents develop apps for a range of devices and for multiple types of app. Of the sample, 65 develop for multiple devices (Table A4.10).

Table A4.9 Country of app developer

Country	Interviews
Belgium	1
Finland	2
France	9
Germany	11
Italy	15
Poland	12
Spain	1
Sweden	1
UK	23
Total	75

Source: Oxera based on app developer survey.

Table A4.10 App developers and types of device for which they develop

	Device for which app is developed					
	Smartphone	Tablet	Wearable	Car	TV	Other[1]
Number of app developers	74	61	25	5	7	27

Note: [1] Includes home appliances, cities, industrials, Internet of Things, and company-specific apps.

Source: Oxera based on app developer survey.

Table A4.11 Categories of apps

Entertainment	48	Dating	10
Games	31	Travel	24
Messaging	30	Shopping	30
Health	28	Education	33
Productivity	48	Maps	31
Knowledge/News	31	Other	21
Enterprise applications	46		

Source: Oxera based on app developer survey.

The majority of the respondents are employed by a company based in Europe (65 out of 75), and the apps they develop have an international reach, as highlighted by the 52 app developers who said their apps are downloaded outside their country.

The sample of app developers comprises 18 developers who work only with Android and the 57 who multi-home on at least one other OS. More than half of the respondents (47 out of 75) create apps for iOS, with almost a third (21 out of 75) creating for Windows OS as well. Of the app developers who multi-home, 65% choose to make their first version of the app for Android. In creating their apps, 62 out of 75 app developers used some Google Play services functionalities in their app, while 53 app developers also use third-party APIs. The ability to use the same code on multiple devices is very important for the 90% of the app developers who release the same or a similar app for more than one device.

The Google Play Store is used by all the Android app developers who release their apps on the market, with a few also publishing them on other Android-compatible app stores, such as Galaxy Apps (7 developers), Opera Mobile Store (4), 1Mobile (3), Aptoide (3) and GetJar (1). In our sample, 9 developers do not publish their apps or only release them internally for the company that employs them.

The annual revenues from apps range from a few hundred euros to millions, as summarised in Table A4.12. The information of the sources of monetisation chosen by the app developers is incomplete because many respondents refused to answer. However, 18 app developers said they monetise their app through advertising, which covers on average of 45% of their revenue. In-app purchases are used by 14 respondents, representing on average 27% of their revenue, while app subscription monetisation is used by 9 respondents, representing on average 41% of their revenue.

Table A4.12 Revenues of apps

Revenue	Full-time
Less than €10,000	31%
€10,000–€50,000	18%
€50,000–€100,000	10%
€100,000–€1,000,000	26%
More than €1,000,000	15%

Note: Based on the answers of non-contractor app developers.

Source: Oxera based on app developer survey.

Processing of the app developer survey

To avoid priming the respondents' answers with an exhaustive list of options, the app developers' survey included some open-ended questions about different aspects of the Android platform. Oxera has summarised the answers to the following questions in order to quantify how many app developers expressed the same views.

- 'Can you tell me what are the benefits to you as a developer from using the Android ecosystem?'
- 'What benefits do you get from running the same or similar apps on different devices?'
- 'How does developing for other mobile operating systems compare with developing for Android?'
- 'What are the benefits of providing your app(s) through the Google Play Store?'
- 'What are the advantages and disadvantages of the fragmentation within the Android operating system for you as a developer?'

Based on the questions above, Oxera found that:

- 42 developers considered the large user base of Android to be a benefit;
- 59 mentioned the tool/knowledge/documentation available/Android developer community as a benefit;
- 24 mentioned the flexibility and innovation potential that the open source Android systems offers to their app;
- 52 are dissatisfied with or cannot see any advantage in the fragmentation of Android;
- 11 mention their benefit from access to older devices due to the existence of fragmentation in the Android OS;
- 42 mention that the coverage of Google Play Store is a benefit.

The app developers are vital to the Android platform, and their decision to participate depends strongly on the benefits they receive from the entire ecosystem, of which access and documentation are the most important.

A4.6 Device manufacturers' survey

The device manufacturers' survey covered 10 device makers from 8 countries with a range of devices, such as smartphones (4), tablets (3), wearables (3), car devices (4), Internet of Things devices, sensors, and home or industrial smart devices (8).

Table A4.13 Country of device maker interviews

Country	No. of interviews
UK	2
Switzerland	1
Spain	1
Hungary	1
Italy	1
Greece	1
Belgium	1
Turkey	2

Source: Oxera based on device manufacturer survey.

All 10 device makers use the Android OS for their products, with 8 respondents also using other OS. The Android values stack is modified by 9 of the respondents, with 7 of them maintaining compatibility with the wider Android ecosystem. The products they are manufacturing are sold at a wide range of price points between €1–€50 and more than €1,000, with smartphone and tablet being priced between €101 and more than €1,000.

When asked about the main advantages of Android, 8 out of 10 device manufacturers mentioned the large number of users or app developers on the other side of the platform. Similar to the app developers, 7 device makers mentioned that Android as an open source OS is valuable to them because it offers the freedom to customise their products according to their needs. For 7 respondents, the Google Play app and services enables them to provide a consistent user experience, and 6 consider that it would be harder to keep their device up to date without these.

The survey also explored what factors the device makers found important when choosing an OS. Based on a count of those who said a factor is 'very important' or 'important', Oxera found that 9 device manufacturers look for an OS that enables faster development of products, 6 look at the potential to reduce their R&D costs, while 9 value an OS that allows them to produce cheaper devices.

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