A Comparison of Deflators for Telecommunications Services Output

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ABSTRACT

The telecommunications services industry has experienced significant technological progress yet the industry's output statistics do not reflect this. Between 2010 and 2017 data usage in the UK expanded by nearly 2,300%, yet real Gross Value Added for the industry fell by 8% between 2010 and 2016, while the sector experienced one of the slowest rates of recorded productivity growth. The apparent disconnect between rapid technological improvements and the measured economic performance of the industry can largely be resolved by strengthening the deflators applied to nominal output. We contrast two methodologically distinct options, concluding that telecommunications services prices fell by between 37% and 96% from 2010 to 2017, considerably more than the current deflator. The real output of the sector will therefore have been considerably higher than indicated by current statistics.

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1. Introduction

Users of National Accounts data, including Gross Domestic Product (GDP), usually want to analyse the data in real terms for purposes such as comparison through time. This requires the deflation of nominal values. Statistical offices calculate National Accounts deflators in compliance with international guidance, but there are well-known challenges in constructing deflators, in particular how to treat new goods entering the consumption basket, quality change which may change the price as well as the nature of the product, and products reaching 'corner solutions', such as where prices fall to zero, or where consumption at a given price is without limit.

These particularly affect high-tech and digital products, as engineering progress has been rapid over the last twenty years, and big increases in usage have been accompanied by large declines in unit price. This paper explores these issues with respect to telecommunications services, as the industry clearly manifests these challenges.[1,2]

As demonstrated in ONS (2018), the telecommunications sector has gone from being one of the two fastest growing industries in the UK in terms of productivity in the pre-Great Recession period, to being one of the two seeing the biggest decline, recording negative productivity growth in 2012-17. This has led some (including official reports such as Bean (2016)) to suggest the official deflators understate 'true' declines in the price of such products, and therefore that real economic growth may be understated.

Our contribution is to show that both a modest improvement in the current method for constructing the output deflator for the product and a more radical alternative method show the price decline to have been between 37% and 96% over an eight-year period, compared with the 3% price increase shown by the current deflator. Our alternative improvements to the current price index for telecommunications services, taking account of broadband data services suggest that the real output of telecommunications services in the UK (and likely other countries too) will have been significantly understated in recent years. As these are an intermediate input into other sectors, there will be consequential implications for the sector distribution of output, but potentially also for real GDP and economy-wide productivity estimates, as the UK moves towards double-deflated National Accounts.[3]

Similar issues apply to sectors where digital technologies have driven improvements in services, but they are dramatic in the case of telecommunications services. There has been exponential growth in the quantity of data transmitted via telecommunications networks in recent years. Intuitively, this huge gain in data transmission performance at constant or declining cost should represent a significant gain in real output, irrespective of the content transmitted by the data, or the price charged for this content. This

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1. Telecommunication services comprises four sub-categories in the International System of Industrial Classification of All Economic Activities (ISIC) 2008 system: Wired telecommunications activities (6110), Wireless telecommunications activities (6120), Satellite telecommunications activities (6130) and Other telecommunications activities (6190). Note, however, that the deflators we are comparing in this paper are product level deflators. They are therefore informative about price changes for the product telecommunications services, rather than price changes for the industry as a whole. Whilst most telecommunications services are produced by the same industry, some of that activity also takes place in other industries.

2. In 2016 the Office for National Statistics (ONS) joined with leading economists and engineers in the Institution of Engineering and Technology (IET) to review this issue. A previous ONS article (Heys & Awano (2016)) outlined some of the key conceptual issues in scope.

3. See ONS (2018a)

paper does not venture into all the complexities of new digital goods, or boundary issues concerning where they are produced (see, for example, Coyle (2017)), but focuses on a simpler question: the measurement of telecommunication services output in real terms and what difference alternative approaches for calculating deflators would make.

We consider both an improvement of the current methodology and an alternative data usage driven approach. These provide wide estimated bounds, so we also consider the degree to which market structure and technological change in the sector may lead to convergence between the two deflators over time. Convergence in the price per unit of data charged currently for different communications services can be expected, primarily through competition between differently priced close substitutes: where customers are currently charged a different price per unit of data this should ultimately lead to the lower cost substitute becoming dominant and winning market share, as long as there is enough competition in the market. Convergence would make a data usage based unit value index a more meaningful proxy deflator. We present evidence that some convergence is under way.

The two options exemplify a key difference between the engineering and economic approaches: economists observe a variety of products with different prices and weights in a basket of goods, delivered via the means of data transmission; engineers observe the telecommunications service sector delivering a single product – data transmitted, which has a variety of uses in delivering different services – which has experienced a clear and substantial fall in cost per bit of data through time.

Our first option presents a relatively cautious updating of the current deflator in line with current international norms and standards, notably adding important components to the basket of goods in scope. The second option starts from the engineering perspective that there is a single service – data – and thus considers a data usage driven approach by translating all services into a single measure of the volume of data and using the revenue per unit of data as the deflator.

The results are striking in either case. Both approaches suggest substantially faster price decline than the present deflator. We find that prices of telecommunications services have fallen by 37 − 96 %. This is significantly lower than the current deflator suggests and implies that the real growth of telecommunications services in the National Accounts has been understated. We also present some potential amendments to our two approaches that may help narrow this range.

The rest of this paper is structured as follows. First, we set out the context. We then discuss the engineering issues in terms of the differences between the various telecommunication services and how to represent the output of all services in terms of bits transported. Then we present the methodology for calculating the current deflator, and the two alternative options; and we discuss their strengths and weaknesses. Finally, we discuss the results and some potential future improvements.

2. Context

Recent questions concerning measurement of the digital economy often re-open, in a particularly acute manner, older debates. Innovation is the defining characteristic of the digital economy, either in the form of new products and services, improved quality and variety, or new business models (such as digital platforms). Innovation in general has long posed a challenge to the construction of price indices, as elegantly summarised by Diewert (1998):

> *"The basic problem is that traditional index number theory assumes that the set of commodities is fixed and unchanging from period to period, so that like can be compared to like."*

Considerable attention has therefore been paid to how innovation should be treated in theory in price indices, and the extent to which this diverges from normal practice in statistical offices.

The naïve approach is to use a unit value index, comparing revenue in two time periods. A unit value is calculated using total revenue and total volume for a particular service. Unit value indices are both dependent on the choice of units deployed, and need the goods to be broadly homogenous as otherwise the price series might be biased. This is because the unit price captures both price and quantity changes. Only if the products are completely homogeneous, and a shift in consumption therefore occurs for some reason other than substitution for product characteristics, is there no bias.[4] Statistical offices sometimes use unit value indices for pragmatic reasons but economic theory favours price indices.

The traditional Laspeyres index answers the question: How much would a given consumer with given preferences need today to make her as well off as she was yesterday *still consuming yesterday's basket of goods*? It therefore forms an upper bound because it rules out consumer substitution when the relative prices of goods change.[5] However, from the perspective of economic theory, the price index should answer a subtly different question: How would a hypothetical consumer evaluate the two different sets of prices and goods? What is the compensating variation that keeps the consumer on the same indifference curve, given price changes and substitutions? For instance, suppose a laptop cost £1,000 in both 2012 and 2017 but the 2017 laptop has much better performance characteristics such as speed and memory. It is possible that a given consumer would be equally satisfied in 2012 and 2017, given what is available on the market and her (socially-influenced) expectations (and hence the intuitive appeal of unit value comparisons). However, to reflect the real growth through innovation, the price ought to record a decline; there has been an increase in consumer surplus.

Hence economists prefer a superlative index such as the Fisher Index, which approximates the theoretical cost of living index that keeps consumers' utility constant. However, superlative indices such as the Fisher require expenditure data for the current period that is usually unavailable when price indices are being calculated. The Laspeyres (or Lowe) index is therefore typically used in practice, (either with fixed weights or annually updated weights).[6]

Given standard practice, there are several ways of reducing the potential bias, employed to differing degrees by statistical offices, particularly after the Boskin Commission Report (1996). One is to update the index weights frequently. Another is to introduce new goods into price indices more swiftly than had previously been the practice, to capture better the rapid price declines that often occur in the early years of the product lifecycle.

A third, often seen as the gold-standard solution to the problem of adjusting for rapid quality change, is hedonic adjustment based on regressions on definable characteristics, in order to link prices per unit "to a yardstick more nearly relevant to its intrinsic utility".[7] For instance, hedonic regressions for computer prices might include processor speed, RAM, hard drive capacity, screen resolution, built-in camera and so on. In effect, products become bundles of more fundamental characteristics. Hedonic adjustment is typically applied to a few goods experiencing rapid change in their quality or characteristics,

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4. Equally, there is not really an index number problem in that case.

5. Conversely, the Paasche will form a lower bound, looking back from today's basket of goods.

6. The Lowe will exceed the Laspeyres in a period when there are long term trends in relative prices and consumers are substituting to lower priced items.

7. Adelman & Griliches (1961)

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accounting for a small proportion of the consumption basket (0.39 % in the UK), in part because of the significant data requirements.[8] To be a solution to the bias, hedonic adjustment also requires the assumption that the price contribution of different components equals their marginal contribution to consumers' valuation of the product.

There is an extensive literature on both the new goods problem and the hedonic approach. On the topic of new goods, the introduction of broadband as a product has attracted noticeable interest. The common approach in these studies is to evaluate quality-adjusted prices using hedonic regressions (Griliches, 1961). Williams (2008) considers internet access prices in the US for the period December 2004 to January 2007. The study uses 135 price quotes from the BLS' CPI database and constructs hedonic functions where the main quality characteristic is bandwidth. Williams finds that quality adjusting the internet access price index makes little difference. Greenstein and McDevitt (2010) use a sample of over 1,500 price quotes for the period 2004 to 2009 obtained from a private consultancy. They use this to construct a hedonic model where the main quality characteristic is the download and upload speed. They find that quality adjusted prices fell by around 3%-10% in the period. This was a steeper decline than the official measure but still much smaller than the quality-adjusted price changes for other products such as computers.

However, hedonic studies have limitations. There is a question about the completeness of product characteristics used in the hedonic regression. Bandwidth and upload/download speeds, while important, are not individually sufficient to explain price and quality changes of broadband. Other factors such as data caps, speed limitations ('throttling') at peak times, latency (round-trip delay) and geographical coverage are important quality considerations of the broadband service itself. There is also interaction with the services available via digital data transmission, and the degree to which access to this data may become more valuable as more products become available to consumers, and as more services become accessible only online. In addition, even the bandwidth needs to be treated carefully as there is a difference between advertised and actual bandwidth. Advertised speeds can remain static whilst actual download and upload speeds improve, and vice versa. Furthermore, actual bandwidth cannot be captured in hedonic functions, as the actual speeds cannot be observed on an individual service contract level.

It is also difficult to construct representative baskets of broadband service contracts, given the complexity of pricing in the industry and the wide range of available tariffs and options available and their dynamic nature. The use of a basket of goods approach in constructing a price index is therefore questionable in this case.

Hausman (2003) discusses some limitations of hedonic regressions in general. He argues that prices in imperfectly competitive markets are determined by demand, cost and the degree of competition in the market, and that hedonic regressions often fail to separate out these factors. In addition, even in the case where a hedonic regression might be acceptable, Hausman argues that it is difficult to identify all the product characteristics that are needed. This is especially relevant where the product characteristics are changing rapidly.

One of the results of the rapid technological change in the telecoms services industry is that the volume weights for the different services differ significantly from their respective revenue weights. For example, while data services are weighted very highly in volume (as measured by bits for all services), the weight of data services in revenue is much lower. A similar problem is observable in the price of drugs. When generic versions of a drug enter the market, the price index is hardly affected, even though the price

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8.   This figure relates to the Consumer Price Index

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of generic drugs is much lower (Griliches 1994). This is because the price index usually uses revenue weights. The incumbents often maintain a large share in the revenue while generics account for the bulk of volume.[9] Griliches and Cockburn (1993) study the prices of generic drugs in more detail and test a variety of different price indices. They find that an average price index (which treats branded and generic drugs as homogenous goods) potentially overestimates the decline in prices. However, their preferred index was much closer to the average price index than the conventional method used in the official statistics.

Price indices, even hedonically adjusted, will anyway fail to capture the consumer surplus due to the introduction of a new good into the market. Feldstein (2017) argues that the failure to consider new products and their impact on consumer value is an even greater source of bias than the failure to account for quality changes. It is difficult to time the inclusion of new goods in a price index and estimate the impact on consumer value using conventional methods.

In theory, and in practice in a few instances, it is possible to estimate the demand curve and hence the reservation price at which demand is zero, when the good is first introduced (Hicks 1940, Hausman 1996, 2003). Hausman also shows this reservation price can be approximated using an estimate of the own-price elasticity of demand. This approach requires current expenditure data, and imposes significant data requirements.

An alternative approach is to measure the cost of the service characteristic directly. This approach has been applied to lighting (lumen hours) and computer processing (computations per second) by Nordhaus (1994, 2007), who constructed long run series of directly observed engineering measures of performance and corresponding supply costs. To the extent the market is competitive and mark-ups remain constant, costs and prices charged should be closely linked. By measuring the price of the service characteristic directly, instead of measuring the price of the goods delivering the characteristic, this approach should therefore capture quality changes and the value of new goods. However, it is usually much more difficult to collect prices of service characteristics rather than prices of goods.

The alternatives to the hedonic approach also indicate substantial upward bias in conventional price indices. However, both involve painstaking statistical and econometric work and are not practicable for the regular calculation of official price indices. A key question we consider here is whether a reliable service characteristic – bits of data transported – can be measured in a way which is both conceptually useful and relatively easy to construct. However, there seems to be no completely satisfactory practical solution to the potential upward bias in price indices in the case of goods and services where there is significant innovation.

This issue remains a live one (see, for example Bean (2016), and work in the US such as Byrne & Corrado (2017) and Groshen et al (2017)). Ahmad, Ribarsky & Reinsdorf (2017) attempt to gauge the scale of the problem by applying different countries' deflators to other countries to see if the magnitude of the resultant volume change is large enough to merit further work. They find that the impacts are relatively small. The weakness of this approach is that comparing a variety of upwardly-biased deflators may differ from a comparison of a more correctly specified deflator.

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9. Although a key question is why the incumbent products are able to maintain this price differential; is this because of some unobserved characteristic or because of a poorly functioning market where consumers are not reacting fully to new price signals

In the context of this debate, this paper considers the deflation of telecommunications services as used in construction of the Output measure of GDP.[10] Telecommunication services have experienced extremely rapid technological change in recent years, and the issues debated in the literature are particularly acute here. Both ONS and EUKLEMS data suggests the telecommunications sector has seen one of the slowest rates of productivity growth in recent years, and yet to a telecommunications engineer this is at odds with the extremely rapid technological progress it has experienced. The sector has also experienced rapid demand growth observed in terms of the volume of data usage, but not total sector revenues.

3. Engineering issues

The key question from the engineering perspective is how to conceptualise and measure the fundamental communications product, 'data', encapsulating broadband (fixed and mobile) data and all other telecommunications services (phone calls, text messages etc). The question concerns both the appropriate volume units of measurement, and the measurement of quality.

Users primarily perceive that they are buying digital products and services of many kinds, from movies to banking services, rather than buying their transportation per se. However, in engineering terms communications, whether traditional telephony, TV/video, banking or social/text networking, is essentially a bit-transport service. An analogy would be that the domestic user may use water to wash, clean, cook and a variety of other purposes, but the water supplier sees only the quantity of water being piped to each home, with charges being driven by the volume of water consumed and the fixed costs of the network. For ordinary physical products they would expect that any transportation necessary to cost an amount relating to specific characteristics such as the product's size and weight, rather than the intrinsic value of the product itself (with some exceptions).

Data services in the UK are provided either via fibre or wireless connections.

The cost of a fibre network is typically dominated by the fixed costs of installation, which has not changed much in recent years.[11] However, the data rate achieved on a single installed fibre has risen by some 10^{10} times (from 0.1MBit/s to 1 Petabit/s) for 'champion' results between 1960 and 2015.[12] Similarly, the data rate for widely-installed systems rose 10^6 times between 1980 and 2015 (from about 1Mbit/s to about 1Terabit/s).[13] These improvements each broadly equate to a fairly steady log growth gradient of 150% per annum or 5000-6000% per decade.[14] Although there has been some levelling off in the

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10.   GDP can be calculated by the Output, Expenditure or Income approaches. To ensure that the three approaches yield the same estimate in practice, National Accountants use a balancing process.

11.   Meaning civil engineering (construction) for the most part.

12.   Champion results are those achieved in best case experimental systems. See Ellis et al (2016)

13.   These gains in volume for similar or falling cost should deliver equivalent gains in productivity. Indeed if we were producing bags of sugar instead of digital bits it would. Today's annual sugar consumption in the UK would, if spread evenly across the national surface area amount to barely more than the thickness of an oil film on water (4 microns or about 1/30 the diameter of a human hair or optical fibre). But if the gains since 1980 in installed fibre systems were applied to sugar the UK would now be covered by an extra depth of four metres of sugar each year.

14.   Interestingly, similar to Moore's Law.

champion rates in recent years these are considerably higher than the installed rates. This means that large further gains in the installed rates remain possible.

The conversion rates of different products into bits or bytes of data are key to volume measurement. From a network perspective, there is little difference between a voice call and, say, a Skype or WhatsApp call, beyond the differences in bit/s that they use. We have used the conversions shown in Table 1 for converting voice and text services into generic data services.

Table 1: Data conversions

Medium	Bytes / kBytes rate	Other factors	Aggregate Bytes/ kBytes required
Voice	32 kBit/s each way	a) x 2 for a two-way call b) /8 to convert kBits to kBytes c) x 60 to convert seconds to minutes	480 kBytes per minute
Text	1 byte/character	a) x 140 as maximum of 140 characters per text.	140 Bytes per text

We make a number of simplifying assumptions:

- For text, we ignore shorter/longer messages and 'emoticons' for simplicity and assume all texts are 140 characters long, although many modern text systems will use more characters;

- A traditional voice call can reduce the data rate to a 'holding' level if both ends happen to be silent, and many systems exploit the relative tendency for both ends not to be speaking together, but we do not adjust for this;

- Similar arguments apply to picture and video compression, which will depend upon the characteristics of the particular images involved, and will also likely change over time with technical developments.

Differences due to these simplifications are modest compared to the scales involved. It should be noted that, although for most services the total number of bits moved within the service period is the dominant consideration, other characteristics also matter. For example, latency (the total end-to-end transmission delay) is important in voice calls and some other services, as is coverage – i.e. whether or not you are in range of a transmission point. However, in most cases, these considerations are modest compared to the basic cost-per-bit-moved and we do not consider them at present. Other traditional cost factors, such as transport range, are much less significant in modern digital communications.[15]

Technological change means there is convergence between services both from a network perspective and from the perspective of users. For example, voice calling (once called telephony) is still distinct in terms of how it is handled and charged for by the network (and also, mostly, by regulators), but from a user perspective it is increasingly equivalent to services like Skype and WhatsApp that provide voice calls on the 'data' network, which is subject to a different pricing regime. The same is true of texting; indeed the word once meant SMS but now covers any of a wide range of text-chat services that in fact use the data network, but have the same (or better) functionality for the user. This means there are significant price

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15. Although this was always true to an extent not obvious in the pricing of, for example, international telephone calls.

differences for similar services, particularly when converted into price per data bit. There can still be major cost differentials between similar bit rates carried on different network services and at different ranges.[16] It is likely that the kind of service people use on their devices, fixed or mobile, will continue to shift rapidly in ways that are generally hard to predict.

This therefore leads to some key questions for our construction below of an index based on units of data:

- How long will different products (telephony, texting, data usage), all of which are essentially end-presentations of the same product (data), continue to be regarded as different services by users?

- How long will price differentials exist for these products?

- As cheaper substitutes become available, how long will providers continue to supply these services in the old mode; In other words, how long will telephony providers deliver telephony distinct from data rather than port across to using a IP protocol technology delivering the same user service using less data and at lower cost?

- Is it therefore appropriate or not to consider, for example, Skype and telephony as substitutes?

Boiling these down, therefore, presents a new challenge to price indices methods, namely, what happens when, rather than an old good being replaced by a new good, multiple old goods converge into a single new good?

4. Alternative deflators

Next, we discuss the current method in the UK for constructing the output deflator for telecommunication services, and two alternative options.

The first option is an improved Services Producer Price Index (SPPI), using the same methodology as at present (which employs unit value indices). The current SPPI treats voice and text as distinct services, and does not include data services. Adding data into the basket presents one route for improving this deflator. Option A below describes how we implemented this approach.

The other is an alternative unit value index based on data usage. In assuming perfect substitutability, this latter data usage approach would in theory reflect pure cost-based changes. Given the caveats about this assumption, discussed above, it should be interpreted as a downwardly-biased estimate of the change in prices that would keep consumer utility constant. Option B presents this new unit value index.

Our two options can be considered respectively as upper and lower bounds to some ideal constant utility index, perhaps a hedonically-adjusted superlative index.

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16. Use of the data network is generally cheaper and normally distance-price-insensitive. There can be other differences that are important to the user such as the use of encryption and the blending with video and picture transmission, but the overall effect is to make all services look like bit transport from a network perspective. The phone network has clear guidelines on the maximum latency allowed, to avoid the sort of difficulty that makes voice 'calls' using geostationary satellites as often seen on TV so unsatisfactory. Data network based voice calling services like Skype once had similar problems, but overall improvements in networks have largely solved these to the extent that broadcasters sometimes prefer them to traditional telephones.

4.1 Current method

In the UK, the Office for National Statistics (ONS) currently deflates telecommunications services output at the domestic aggregate level using an index which comprises two components: the product level index of the Consumer Price Index (CPI) covering Telecommunications Services and Equipment; and the product level index of the Services Producer Price Index (SPPI) covering Telecommunications Services.[17] These are weighted around two-thirds CPI and one-third SPPI in the current deflator.

Figure 1 shows the overall deflator currently used in the UK.

Figure 1: UK telecommunications deflator

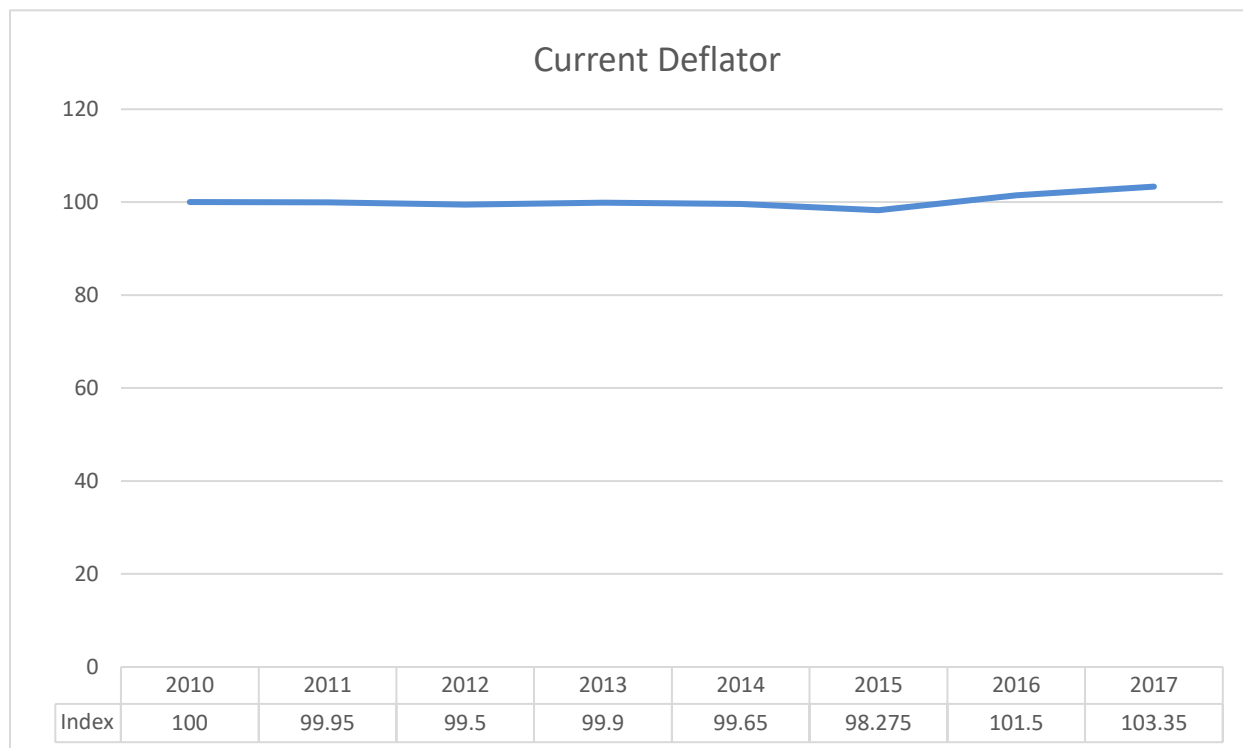|	2010	2011	2012	2013	2014	2015	2016	2017
Index	100	99.95	99.5	99.9	99.65	98.275	101.5	103.35

Figure 2 shows the movement of the different component indices between 1998 and 2017. While the SPPI shows a general downward trend, the CPI declines until around 2008 and then starts to rise again. Since CPI is more heavily weighted in the output deflator, the overall impact is that over recent years the deflator was broadly flat and then began to rise after 2015. Between 2010 and 2017, for example, the product deflator for Telecommunications Services has increased by around 3% despite substantial technological advances in that period (such as the shift from 3G to 4G technology).

While this approach meets international standards, it is a methodology borne out of pragmatic decisions needed to deliver an appropriate deflator for the sale of telecommunications services to businesses and consumers in the UK. These are:

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17.   Import and exports are treated separately.

1. The shares of the CPI (reflecting business-to-consumer sales) and SPPI (reflecting business-to-business sales) reflect broad patterns in the UK economy, but may not be reflective at the product level.

Figure 2: Components of GDP(O) Deflator in the UK
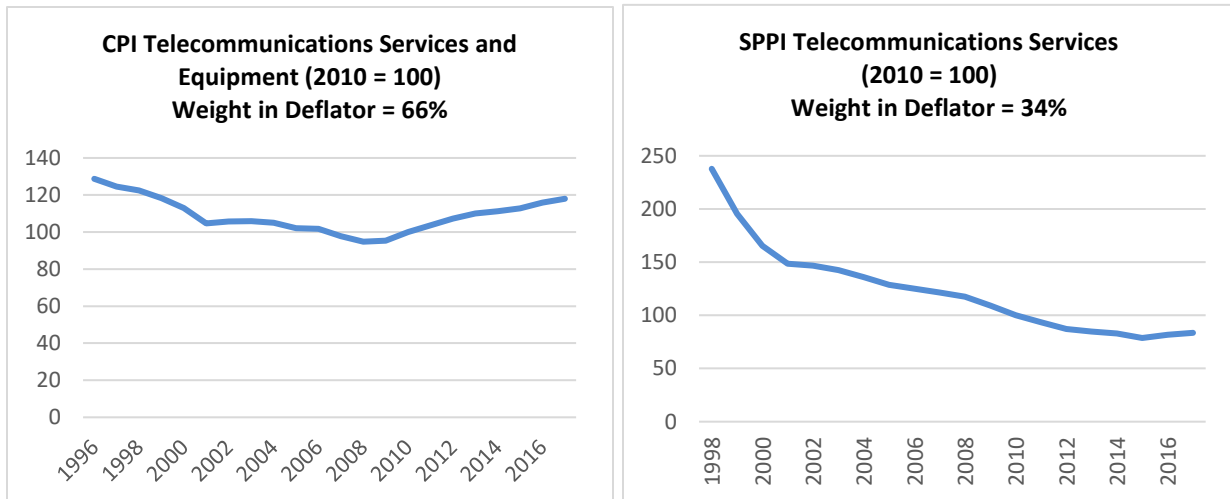
2. The inclusion of the CPI is necessary because the SPPI captures only business-to-business transactions and therefore excludes consumer sales. Whilst the CPI reflects business-to-consumer transactions, it does so in consumer purchase prices. These include wholesale and retail margins and costs and so do not strictly map to the price of interest, the basic price of telecommunications services producers before logistics, retail and margins.[18]

3. The CPI product level index captures both goods and services, despite the product group to be deflated including only services. The CPI and the product group that is deflated are also classified using different systems that do not easily map to each other.[19] This pragmatic compromise may introduce potential biases.

4. Many of the CPI item level indices are constructed using the traditional 'basket of goods' approach.[20] This means that price data is collected for a representative basket of telecommunications equipment and service contracts. A notable exception to this is the item level index for mobile phone charges, which includes Pay As You Go and contract charges. Due to the complex pricing structures and range of tariffs in the market, it is difficult to construct a representative basket of tariffs. Instead, this item is constructed using a "basket of consumers"

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18. Purchaser's prices *minus* taxes *plus* subsidies *minus* distribution and retail mark-up *minus* impact of import prices *equals* basic prices

19. The CPI is based on the Classification of Individual Consumption According to Purpose (COICOP) while the National Accounts product classification is based on the Classification of Products by Activity (CPA). The SPPI classification is based on CPA.

20. Item level indices are below product levels indices. For example, the item level index for Smartphones would form part of the product level index for Telecommunications Services and Equipment.

approach recommended by Eurostat.[21] The ONS obtains representative consumer profiles from the UK's telecommunications regulator, the Office of Communications (Ofcom). For each consumer profile, the ONS tracks the price for the cheapest available tariff from the main service providers. These are then weighted together using expenditure shares which are also supplied by Ofcom.[22] This approach has problems, particularly when quality change needs to be taken into account. The cheapest tariff is often based on old technology while the price of the new technology declines and the old technology is phased out. In this case, significant price movements in tariffs based on new technologies are missed, even if most people are using the new technology. It should be noted that even when a representative basket of tariffs can be constructed, hedonic adjustments would still raise some issues. For example, the headline speed for a tariff (which might be used for the hedonic adjustment) might remain constant while actual achieved speed increases (or indeed decreases, for example due to increased contention). Likewise, other quality aspects such as coverage would also be omitted since these cannot be determined on an individual tariff basis as they depend on network and geographical region. As a result, actual quality changes might not be reflected in the price index, even when using hedonic methods.

5. With the exception of smartphones, none of the item level indices in the CPI: Telecommunications Equipment and Services are hedonically adjusted to control for quality change within the twelve month life of the 'basket of goods' before new products are selected. In a fast-moving sector where contract design can change significantly and quickly this is a major weakness.

6. There are methodological differences in the way ONS constructs the product level CPI and SPPI, as well as differences in the construction of item level indices within the CPI. While the CPI: Telecommunication Services and Equipment is constructed as a price index, the SPPI: Telecoms Services is a unit value index. The ONS obtains administrative data sets from Ofcom. This includes volume and revenue of calls (by type) and text messages. A unit value (or average price) is then calculated for each item and aggregated up, based on revenue weights. The data for fixed line telecommunications only captures business telephony but the mobile data captures the entire market. Since the SPPI at present only attempts to cover business-to-business transactions, an assumption is made about the proportion of the total mobile phone revenue that is due to business use.

7. The SPPI has not been kept fully up to date with the pace of change in the sector. A notable absence from the SPPI is mobile and broadband data.

Irrespective of the two options we present in this paper, the ONS is committed to reviewing and updating the current deflator, not only stimulated by the work described here and the digital economy agenda, but also by mandated changes through the implementation of the European Union's Framework Regulation Integrating Business Statistics (FRIBS) regulation. The FRIBS agenda requires expanding the scope of the SPPI to cover business-to-all transactions, not just business-to-business. This suggests that the ONS, alongside the two options presented below has a *de minimis* alternative of moving to exclusively

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21. http://ec.europa.eu/eurostat/documents/272892/7048317/HICP+recommendation+on+telecoms+-+June+2015

22. For details, see the CPI Technical Guide (page 58-60): https://www.ons.gov.uk/ons/guide-method/user-guidance/prices/cpi-and-rpi/cpi-technical-manual/consumer-price-indices-technical-manual--2014.pdf

using the SPPI and dropping the CPI component from the output deflator. This would resolve issues 1-6, but would still leave issue 7 unresolved, which would be unsatisfactory.

4.2 Option A: An improved SPPI

Under this option broadband and mobile data are added to voice and text in the current SPPI. To reflect the potentially large difference in consumer values, we construct granular unit value indices and aggregate them together using revenue weights. This is largely based on the current SPPI but with major differences: the index includes mobile and broadband data, uses a business-to-all transactions basis, and is annually chain linked. Removing the CPI component from the deflator and using the improved SPPI produces an index showing that telecommunications services prices have declined by around 37% between 2010 and 2017 (Figure 3).

This method presents key benefits, as it is readily comparable to other deflators and represents a cautious improvement to the existing methodological framework. By constructing granular item level indices and aggregating them up, this method also accommodates the possibility that the different telecoms services are heterogeneous products rather than perfect substitutes.

However, the key weakness of this deflator is that it does not reflect the significant technical and quality improvements in the industry from an engineering perspective. This is because the deflator uses revenue weights and therefore underweights data services, which is the area driving technical progress in the industry.

Figure 3: Option B - Improved SPPI deflator
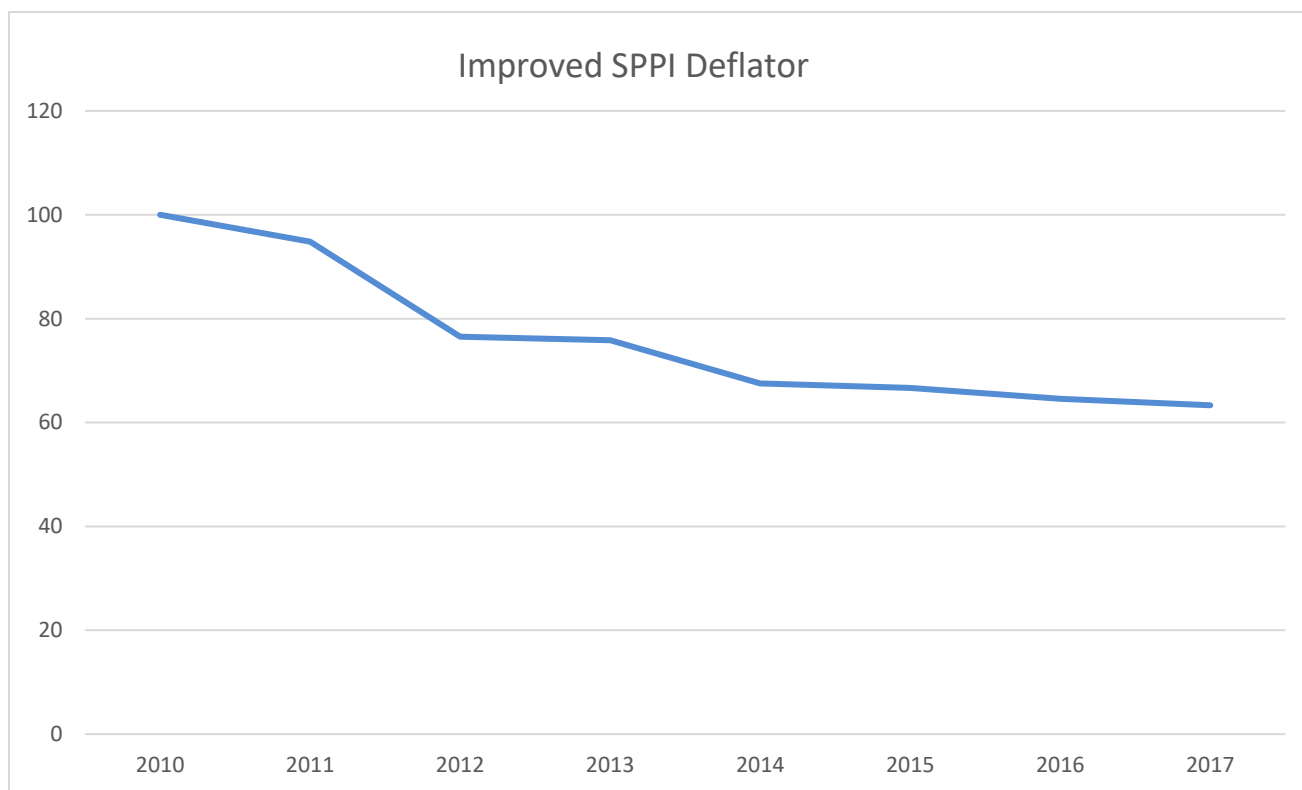
The breakdown of this deflator into the item level indices shows a significant difference in the price movement of the data elements and the voice and texts indices for both fixed line and mobile services (Figure 4). The data items thereby show substantial price decreases but are lower weighted and thus only have a limited impact on this overall SPPI index.

Figure 4: Breakdown of improved SPPI deflator[23]
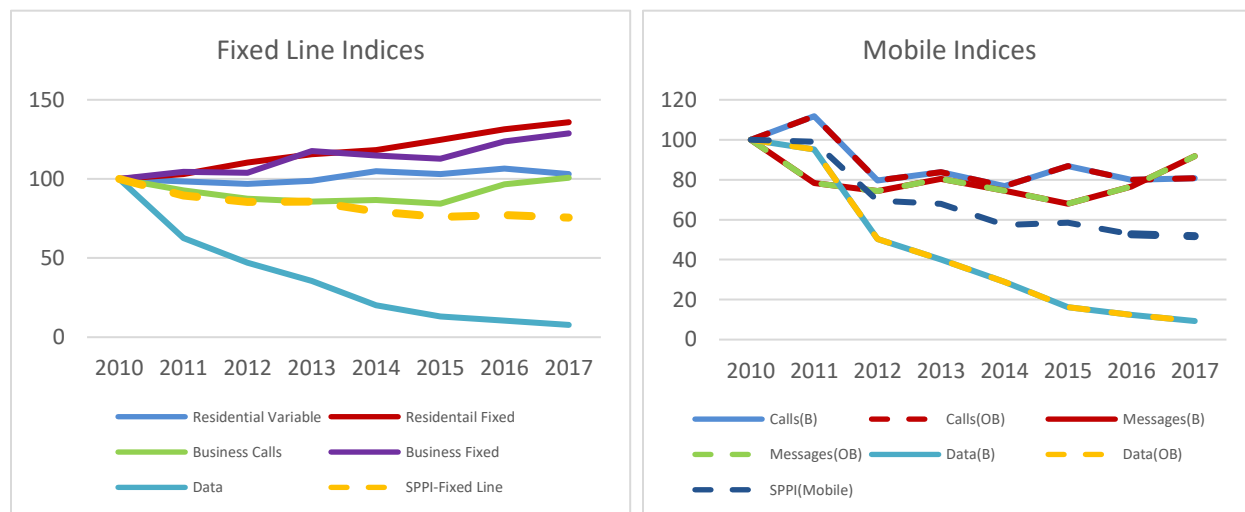
A particular challenge with this deflator is the treatment of fixed line access charges. While the revenue from voice, texts and data can be divided by the volume of minutes, texts and bits, the only common denominator to construct unit values for access charges is the number of subscribers. As a result, the item indices for access charges show an increase in prices but different patterns for residential and business subscribers. For residential subscribers, the price of line rental has increased much faster than the number of subscribers. For businesses, the number of subscribers declined substantially but the corresponding revenue decline from access charges was less pronounced. This suggests that the price for business line rentals also increased.

While access charges and the treatment of bundled items are areas that warrant further attention (see Annex C for technical details), a general feature of option A is that compared to option B below it places a lower weight on the contributions of broadband and mobile data. This is due to perceived substantial price differences between the different services, and the fact that access, voice and text charges currently contribute a higher share of telecoms revenue. A raw increase in data consumption therefore has a limited impact on the Option A deflator, whereas substitution away from voice and text services toward data-driven alternatives such as Skype and WhatsApp manifest as a price increase.

4.3 Option B: Data usage approach

An alternative approach is to incorporate the engineering perspective on the industry's output, seeing the primary service of the industry as the transfer of data.

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23. In the breakdown of the Mobile Index, OB refers to Out-of-Bundle charges and B refers to Bundled charges

Converting the voice, texts and data services into a common volume measure (petabytes of data) shows that broadband and mobile data account for almost all of the volume. It also shows that industry's output, as measured by data transmitted, has increased 2,300% between 2010 and 2017, primarily driven by the increase in broadband and mobile data volumes. The volume of voice calls and text messages has been decreasing since 2010. This is either due to a drop in demand or, more likely, due to a substitution away from traditional telephony toward data-driven applications.

By 2017, around 99.8% of total volume was estimated to be broadband and mobile data. This is in stark contrast to the revenue weights, where broadband and mobile data account for around 40% of the total in 2017. In contrast to the exponential increase in volumes, total industry revenue fell by around 6% between 2010 and 2017 (Figure 5). This is mainly due to a 47% decrease in wholesale revenues. Retail revenues increased by around 9% in the same period (see Annex A for details).

Figure 5: Revenue and volume in telecommunications services industry
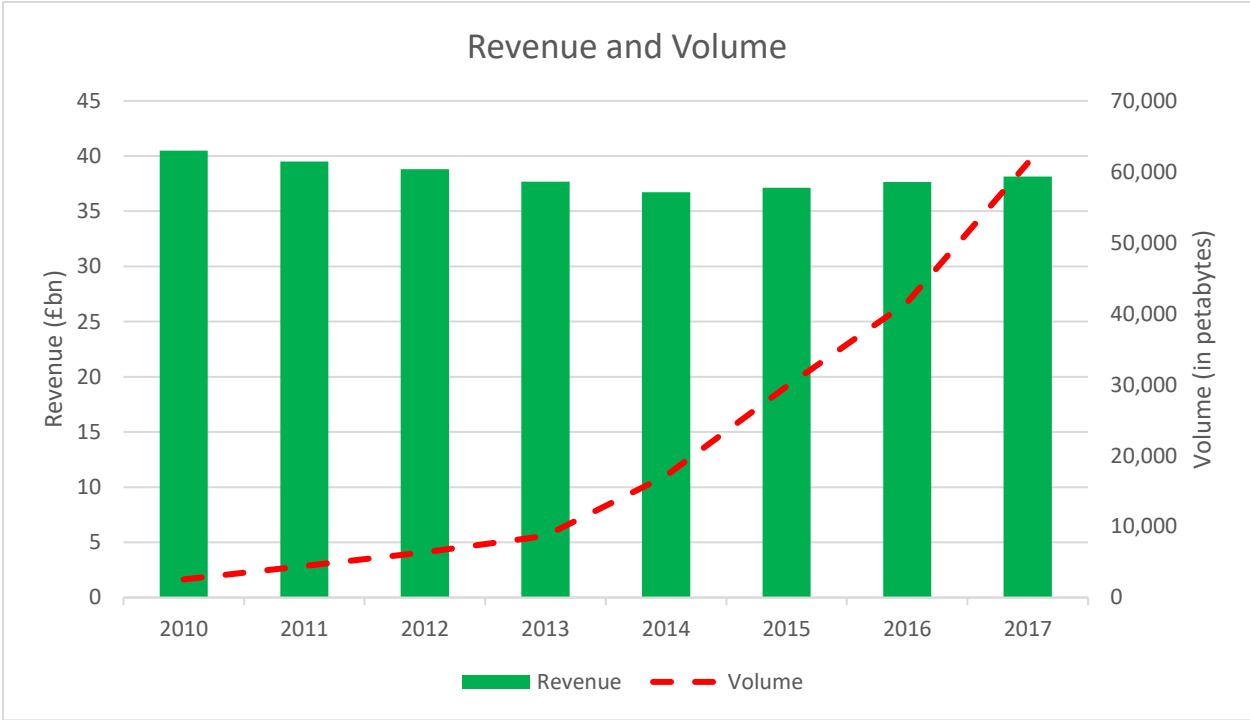

Our Option B deflator is constructed using an aggregate unit value, which divides total revenue in the industry by the total data volume (see Annex B for details).[24,25] This unit value index represents the average price per bit transported. Between 2010 and 2017 this measure suggests that telecommunications services prices decreased by around 96%, as shown in Figure 6. An increase in data volume, with revenue broadly staying flat, is seen as a volume increase and a price decrease. Likewise, a substitution away from

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24. The total revenue figures exclude non-communications revenue such as TV bundles.

25. The total volume excludes wholesale and corporate volumes. This does not impact on the main results, see Annex D for details.

pricier voice calls and text messages towards cheaper services such as Skype and WhatsApp is also seen as a volume increase and a price decrease.

Figure 6: Comparing improved SPPI (Option A) and data usage (Option B) deflators
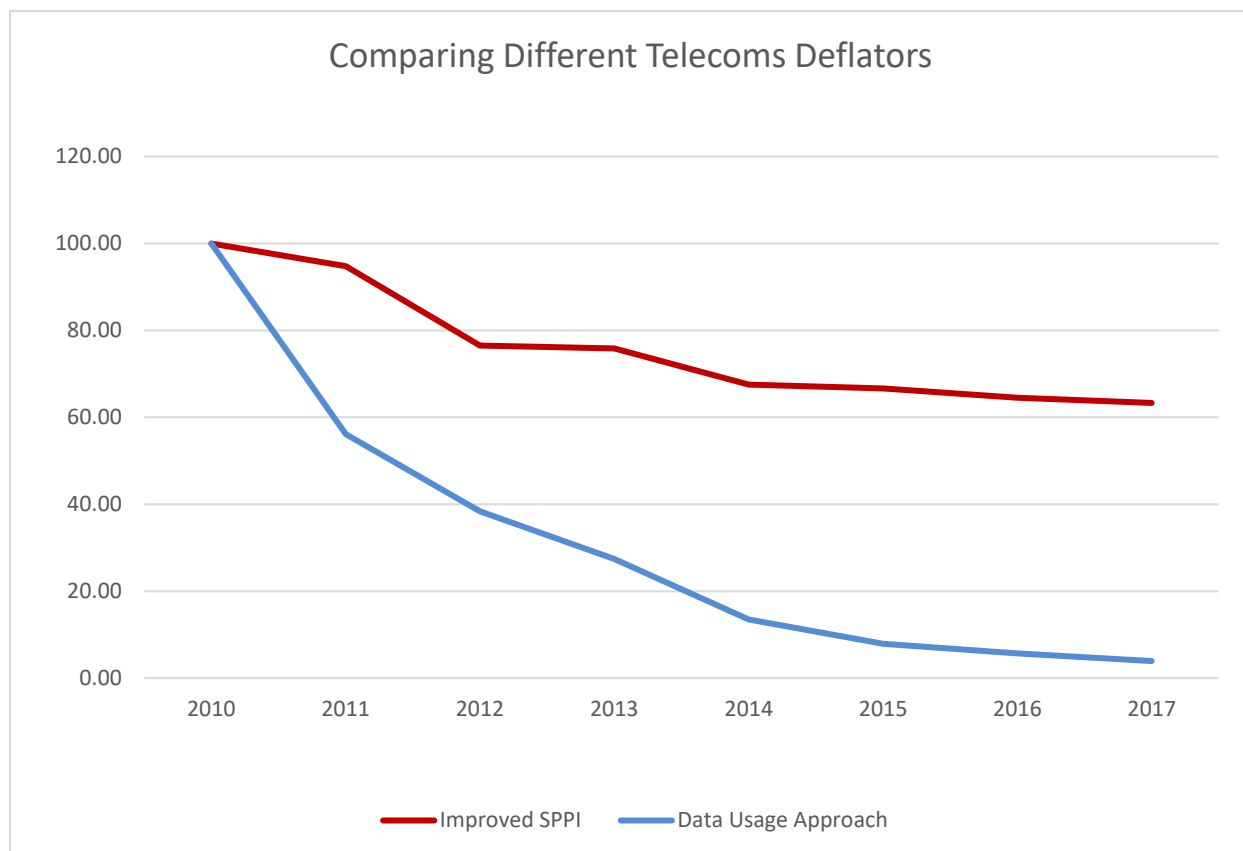
The merit of the Option B data usage approach is that it better reflects the significant technical advances in the industry. Many of the technical and quality changes that have occurred are manifested in an increased data volume, without further quality adjustments, as some aspects of quality are implicitly inherent in the measure; increased coverage, for example, allows more people to get access to telecommunications services and thus increases data traffic. Likewise, an increase in speed increases volume as users can consume more data in any given time period. Finally, future changes in technology may be more easily reflected in a data usage based deflator. This is because, as long as the service is defined as the transport of data, any new technology or service will be adding to the volume of data. The impact that the new service will have on prices is then determined by its impact on total revenue relative to its impact on total volume.

The key weakness with this option is that it takes no account of the differential prices currently paid for different communication services. This is vital as consumers do appear to assign different values to the different services, reflected in the differences in prices. However, whether the prices truly reflect consumer utility from different telecoms services can be questioned. Our initial analysis indicates that phone calls cost many multiples per data unit of the equivalent data service, for example by looking at out of bundle charges. While there could be a stronger preference for traditional call and text services, it

seems unlikely that the strength of preferences alone could explain the observed magnitude of the difference in prices.

5. Discussion

Our results show a substantial difference between the improved SPPI and the data usage approach, although both reveal a large decline in prices compared to the current methodology. And while both deflators are improvements compared to the current method, their incremental impact on real output growth in the sector would differ significantly in terms of magnitude. The key question is how to narrow this wide range and ultimately deliver a method that might be applied in the National Accounts.

Two possible extensions to the work described here are: first, to consider quality adjustment of the SPPI Index, using some of the characteristics of telecommunications not captured presently, such as coverage and latency; secondly, to consider whether the data usage approach can be improved by considering the fixed infrastructure element in both the delivery and the pricing, which has been increasing in recent years. The index presented here attributes all the costs to the data transmitted. These improvements might help to narrow the gap between these two approaches, but we may need to start with a more basic question, namely why they show such different results in the first place?

The market for communication services is in a period of rapid innovation, resulting in changes both in pricing and consumer behaviour (including significant growth in data usage), thanks to the remarkable engineering advances. The use of an aggregate unit value measure such as the data usage approach, for all that it is not a true price index without the assumption of homogeneity, is probably closer than the Laspeyres to many people's intuition about the effect of advances in communication services on their economic welfare; but to the degree these advances are not reflected in the narrowing of price differentials, we must ask if there may be other reasons for these price differentials which we need to take into account.

One way to characterise the data usage approach is that broadband and mobile data are 'under-weighted' in terms of revenue, but 'over-weighted' in terms of volume. This is similar to the issue raised by Griliches and Cockburn (1993), that generic drugs were also overweight in volume but underweight in revenue. They argued that some of the price differences between generic and branded drugs (despite their being identical products) could be explained by the brand value consumers attached to the particular drugs. In the case of telecommunications services, it is unclear whether brand value attribution is a plausible explanation for the difference in prices between data used for telephony and data used for pure data services (although there is some evidence for brand value attribution in equipment such as smartphone handsets).[26] The issue is not the price difference for the same service such as phone calls provided by the same operator. Rather, it is the different prices that each operator charges for data services compared to other telecommunications services, even though all can be represented in terms of data use.

In practice, when there are brand new or improved goods, there will be a period of gradual consumer substitution away from the old goods. The diffusion of digital hardware is typically rapid, with reasonably

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26. There is evidence of its impact of telecommunication goods, such as Apple smartphones etc. These are shown to have a branding value in hedonic regressions by the ONS for the CPI. See for example https://www.ons.gov.uk/ons/guide-method/user-guidance/prices/cpi-and-rpi/review-of-hedonic-quality-adjustment-in-uk-consumer-price-statistics-and-internationally.pdf

short replacement cycles, but consumer habits and know-how may take time to catch up. The Boskin Report noted that in a typical product cycle, a new version enters the market at a higher price than old models. When they nevertheless gain market share, "We can conclude that it was superior in quality to the old model by more than the differential in price between the two."[27] This is not the situation across the board in communications, where there is a mix of:

- higher quality and higher price in some services (such as 4G versus 3G for mobile calls and data);

- new, lower prices services substituting for existing ones (such as VOIP versus fixed or mobile telephony, or Rich Internet Applications such as WhatsApp versus SMS);

- bundling of different services, and 'convergence' of services, making price and quality comparisons difficult for consumers (and statisticians).

A possible explanation for the price difference therefore lies in product differentiation in a less than perfectly competitive market. Some specific services may additionally benefit from network effects that would not be captured in market prices. One conceivable unobserved characteristic is the degree to which voice calls and text messaging applications act as platforms, benefiting from significant network effects. While special software or apps might be needed to make a phone call using the data service, the network's own platforms allow the consumer to immediately reach a greater number of people. Once alternative platforms achieve significant market penetration, they become viable alternatives with their own network effects. This, for example, is the case for WhatsApp, which reached over a billion users in 2016.[28] However, to get to this stage, consumers need to know about the existence of cheaper and better platforms. We could therefore be experiencing a disequilibrium situation where consumers need time to learn about these alternative platforms.

Furthermore, traditional platforms can be bundled with the equipment. For example, all smartphones come bundled with a telephone and text messaging app which uses the more expensive services of the telecoms provider. Tariffs too come in bundles usually including an allowance of minutes, texts and data. Since consumers cannot opt out of the voice and text elements, they might continue to use these traditional services. Consumers may also have difficulty in comparing prices across differently-structured bundles. There are surely large information asymmetries.

Bundling, in particular, makes it difficult to draw direct links between prices and quality of service, and makes price comparisons between operators extremely difficult. The spread of triple and quadruple bundles (mobile, fixed line telephony, fixed line internet and TV) means this complexity is increasing, making it difficult to determine actual price differentials between the different services. However, looking at incremental costs for a small number of bundled tariffs, where the principal difference is the voice or data service, suggests substantial price differences. This is also confirmed by looking at out-of-bundle charges, which show that voice calls and text messages are substantially more expensive than their equivalent data service (e.g. Skype or WhatsApp). Furthermore, consumers may never actually use all of the capacity in the packages they purchase, for example having unused data allowances or free SMS messages at the end of their billing period.

Aggregate unit value changes may also capture price changes due to changes in the degree of concentration in the market and the absence of perfect competition. However, the presence of imperfect

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27. https://www.ssa.gov/history/reports/boskinrpt.html#cpi5

28. http://www.bbc.co.uk/news/technology-35459812 [Retrieved: 21 July 2017]

competition and price mark-ups changes the welfare interpretation of any of the potential approaches to quality or new goods adjustment.

The data usage approach clearly presents a lower bound estimate. This would particularly be the case if consumers were substituting traditional voice and text services for data driven ones because they feel poorer and so are switching to cheaper and (by assumption) lower quality alternatives. However, in many ways the alternative platforms are superior in that they provide users with additional information and functionality. WhatsApp (and other messaging apps) for example indicate if a message has been read and allow users to set up status messages that help their peers know whether someone is available to be contacted. Likewise, if consumers attached lower values to general data usage, such as streaming videos or browsing the internet, then these too should have lower weight in the deflator. However, it is not clear that consumers do indeed attach lower values to data services. For after all, data consumption, along with the usage of data-based alternatives to traditional phone calls and text messaging, has been increasing substantially.

5.1 How much does the potential bias matter?

A simple example illustrates the potential scale of the bias in the data usage approach if consumers value services differently. Consider the price of traditional voice telephone calls and VOIP calls such as Skype. The following table is an illustrative example where the price of each service does not change between time periods, but the volume of calls via each method changes, and so total revenues change.[29] We can contrast a Laspeyres/Paasche/Fisher type approach with one that views both traditional telephony and Skype (or any other data driven application) as substitutes, calculating aggregate unit values based on total revenue and total volume.

	Voice telephony			Skype			Total		
	Quantity	Price	Revenue	Quantity	Price	Revenue	Quantity	Revenue	Average price
Year 1	100	10	1,000	10	1	10	110	1,010	9.1818
Year 2	10	10	100	100	1	100	110	200	1.8181

Under this example we can produce the following results, where both the Year 1 price and volume indices are set to equal 100.

	Year 2 price index	Year 2 volume index
Laspeyres/Paasche/Fisher	100	19.8
Aggregate Unit value index (Data usage approach)	19.8	100

A Laspeyres (or Fisher) index by construction in this example shows no price change and a decline of around 80% in volume. It implies that consumers in the second year are buying more Skype and fewer telephone calls, which *by assumption are not substitutable*, for non-price and non-preference-change reasons.

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29. These are not actual prices and volumes and are only used for illustrative purposes: Whilst the above illustration uses a price relative of 10 our initial analysis suggests that the price relative between traditional voice and Skype/WhatsApp calls could be much higher, so the bias could be more pronounced.

By contrast, a simple (aggregate) unit value calculation shows a decline of 80% in the price index between years 1 and 2, and no change in the volume of calls. When products are heterogeneous so that consumers may be substituting to higher quality ones, the data usage approach will be biased (upward if the consumption mix is shifting toward more expensive alternatives, and conversely). In this example, in using aggregate unit values as a proxy to measure price change there is an implicit assumption that *the two products are perfect substitutes*, and consumers are switching from voice calls to Skype entirely for price reasons – and so would within a short time have completely switched so voice calls would drop out of the market. It is not surprising that contrasting assumptions lead to contrasting results.

5.2 Convergence

Despite these caveats, it does not seem unreasonable to assume a high and rising degree of substitutability between different forms of telecommunication services as users' behaviour adapts, rather than assuming none. In this context, the question is then the degree of homogeneity the different services (voice, text, and data). Looking at the price differentials between the services would suggest substantial differences from a consumer value perspective. However, from a network perspective, the different services are broadly similar in that they all involve the transportation of data, typically using the same transmission lines and networks.

Having said that, it is clear that this is a transitional phase, both in technology and in consumer behaviour; and in addition that there might be heterogeneous characteristics of voice telephony that some people will continue to buy, such as reliability or coverage.

While the improved SPPI and the data usage approach appear substantially different at present, in future they might converge. The share of total revenue due to data usage increased between 2010 and 2017 for both fixed line and mobile telecommunications (Figure 7). For example, we estimate that broadband data accounted for around 26% of total fixed line revenue in 2010, but by 2017 this had increased to 43%. Similarly, we estimate that mobile data accounted for around 20% of total mobile revenue in 2010, increasing to 43% by 2017. In both mobile and fixed line telecommunications, the share accounted for by voice calls and text messaging decreased in that time period. If this trend continues, the revenue and volume weights for the different services could converge. This would mean that the (revenue weighted) improved SPPI and the (volume weighted) data usage approach would converge.

Figure 7: Fixed line and mobile revenue shares (weights for the indices)

Mobile Revenue Shares

(Legend: Calls, Messages, Data)
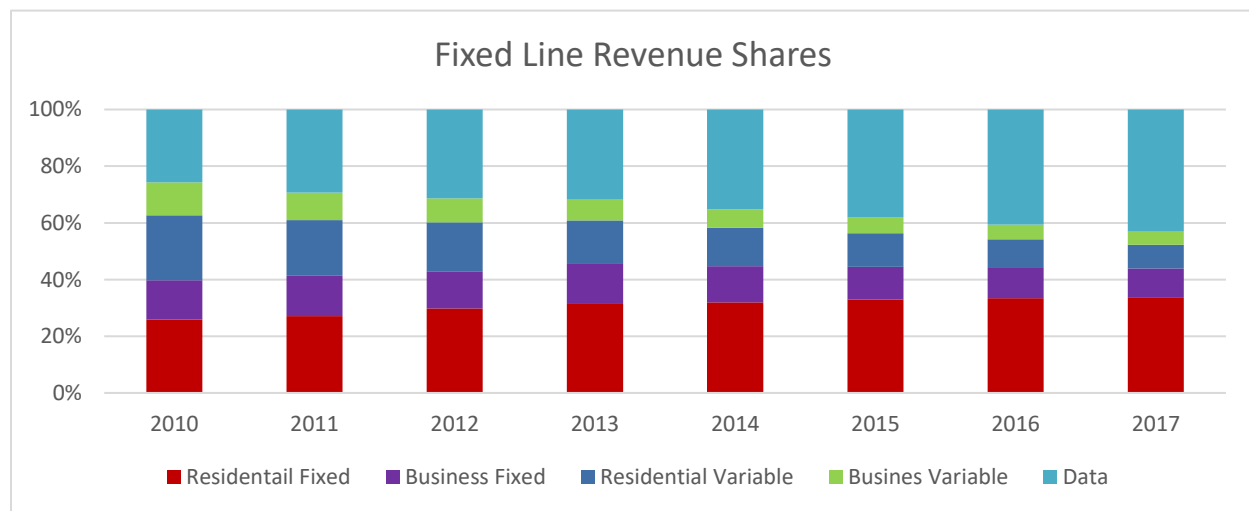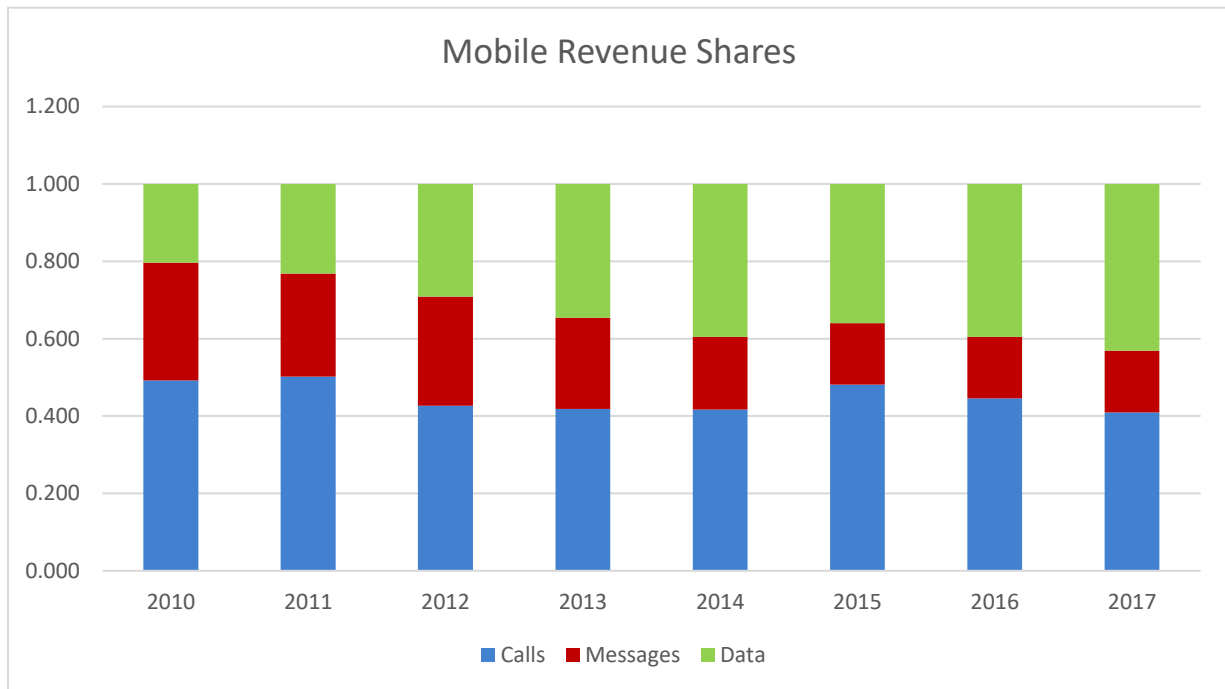
On the face of it, this could favour option A over option B. Since the improved SPPI is chain linked, it could become equivalent to the data usage approach, although this would require further work to establish how to chain link when existing products are converging to become a single, new product. However, until the movements in the two deflators converge, there is scope regarding the 'true' value of the deflator and hence real GDP. The Option A improved SPPI could be seen as a 'backward-looking' index, while the Option B data usage approach would be a 'forward-looking' index, taking into account that all telecoms services are essentially the same type of bit-transport service.

A specific obstacle to convergence at the moment is the existence of access charges, now incorporated into bundled prices. As Figure 7 shows, while the share of call charges for businesses and residential households decreased from around 35% in 2010 to 13% of total fixed line revenue in 2017, the share of residential and business access charges increased from around 40% to 44% in the same time period. If this trend does not reverse, the two deflators as presently modelled will continue to diverge, as we have no effective way to apportion access charges beyond using the number of subscribers, suggesting the need to incorporate access charges into the data usage model as a cautious way forward.

6. Conclusions

The constant utility approach that informs price theory sits uncomfortably with the practical use of price indices based on specific products to calculate real output and productivity for the national accounts. In the early debate about hedonic prices, Milton Gilbert observed that if quality adjustments fully reflected utility, resulting in lower price indices, a bikini would represent equivalent output to a voluminous Victorian bathing costume, "And should this trend reach its limit of no costumes at all, we would have to say that swimsuit production had not fallen, even though the industry was out of business." Zvi Griliches replied that the concept of goods made no sense independent of a utility framework, and one would not say the Victorians were better off because they had bulkier swimsuits. (Quoted in Stapleford, 2009: p322).

Both perspectives have their appeal, which suggests that the choice of approach and index might depend on whether they are the answer to a question about production or whether in fact the question does not concern output and productivity at all but is instead an aspect of economic welfare.

Our contribution in this paper has been to show that a sensible improvement to the current method for calculating a price index for telecommunications services, taking account of broadband data services, results in an index that has declined substantially more in recent years than the current index. However, this will still be an upward-biased deflator, as it does not sufficiently take account of increasing consumer utility due to new goods. An alternative unit value methodology inspired by the engineering improvements and price declines for data transmission results in an index that declines dramatically more. This understates the 'true' price of the communications services concerned to the extent it does not reflect either consumer attributions of value for service characteristics or attributes such as market structure and price differentiation. It is nevertheless informative about the supply-side efficiency of the services.

Improvements to the current price index for telecommunications services, taking account of broadband data services in both options analysed suggest that the real output of telecommunications services will have been significantly understated in recent years. As these are an intermediate input into other sectors, there will be consequential implications for the sector distribution of output, but potentially also for real GDP. We have focused on telecommunications services but similar considerations may apply to other service sectors experiencing rapid digital innovations.

ANNEX A: BREAKDOWN OF REVENUE AND VOLUME IN THE TELECOMMUNICATIONS INDUSTRY

Revenue breakdown (in £bn)

	2010	2011	2012	2013	2014	2015	2016	2017
Wholesale services	10.1	8.9	7.8	7.0	6.0	5.9	5.4	5.4
Retail fixed	12.6	12.4	12.4	12.6	13.0	13.5	14.3	14.7
Retail mobile	15.1	15.4	15.8	15.5	15.2	15.2	15.4	15.6
Corporate data services	2.7	2.8	2.7	2.6	2.5	2.5	2.5	2.5
Total	**40.5**	**39.5**	**38.8**	**37.7**	**36.7**	**37.1**	**37.6**	**38.1**

Notes: 'Corporate data services' comprises web hosting, Ethernet, IP VPN, digital leased line, corporate VoIP and frame relay/ATM services; wholesale mobile comprises wholesale mobile voice, messaging and data services, mobile voice and SMS termination revenue and wholesale inbound roaming revenue (i.e. revenue from overseas operators when their subscribers use UK networks).

Source: Ofcom Communications Market Reports 2016, 2017 and 2018

Volume breakdown (in petabytes)

	2010	2011	2012	2013	2014	2015	2016	2017
Total Voice (PB)	122	116	113	109	105	104	104	97
Texts (PB)	0.018	0.021	0.021	0.018	0.015	0.014	0.013	0.011
Fixed Line Broadband (PB)	2,352	4,223	6,017	8,208	16,495	28,751	40,234	59,280
Mobile Data (PB)	79	99	239	347	542	880	1,270	1,877
Total (PB)	**2,553**	**4,438**	**6,369**	**8,664**	**17,142**	**29,735**	**41,607**	**61,254**

Source: Authors' calculations based on data from Ofcom Communications Market Report 2016

ANNEX B: METHODOLOGY GUIDE TO THE DATA USAGE APPROACH

Data sources

1. We use Ofcom's Communication Market Reports for the years 2016, 2017 and 2018 Tables as a sole data source.

2. We obtain the following data series from the report :

    a. UK Telecoms Revenue

    b. Outgoing fixed and mobile voice call volumes

    c. SMS & MMS messages sent

    d. Average fixed broadband use

    e. Fixed Broadband connections

    f. Average mobile data use

    g. Active mobile subscriptions

3. For the most part, the data points are available for the period 2010-2017. We extrapolate values for missing years.

Constructing the deflator

Converting voice and text to data

4. Bit rates for voice calls can vary and be adaptive. At present we use a working assumption that any system will use about 32 kBit/s each way. A 2-way voice call therefore uses 64 kBit/s or 480 kBytes per minute. Thus:-

Assumption 1: Each voice call uses 480 kBytes per minute

5. Text messages use 1 byte per character, with a maximum 140 characters per text. There may be differences in the way longer/shorter messages or emoticons are handled (especially by text services like WhatsApp & iMessage that go beyond SMS) but for now we use a working assumption that every text message uses 140 bytes. Thus:

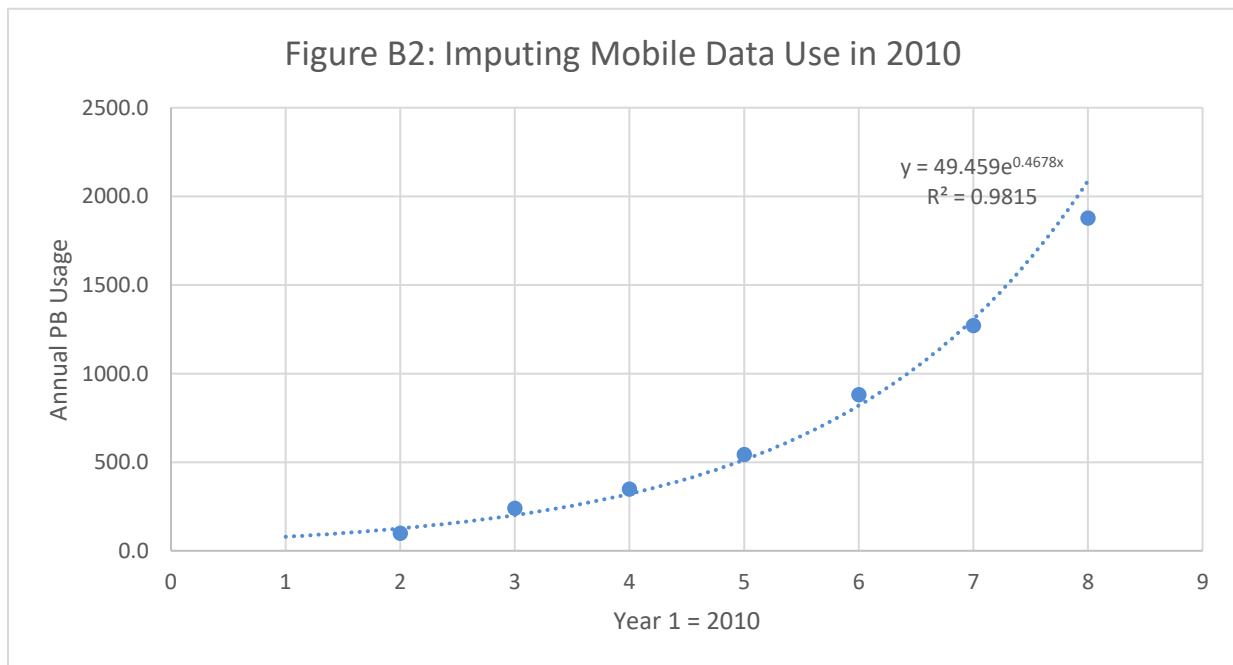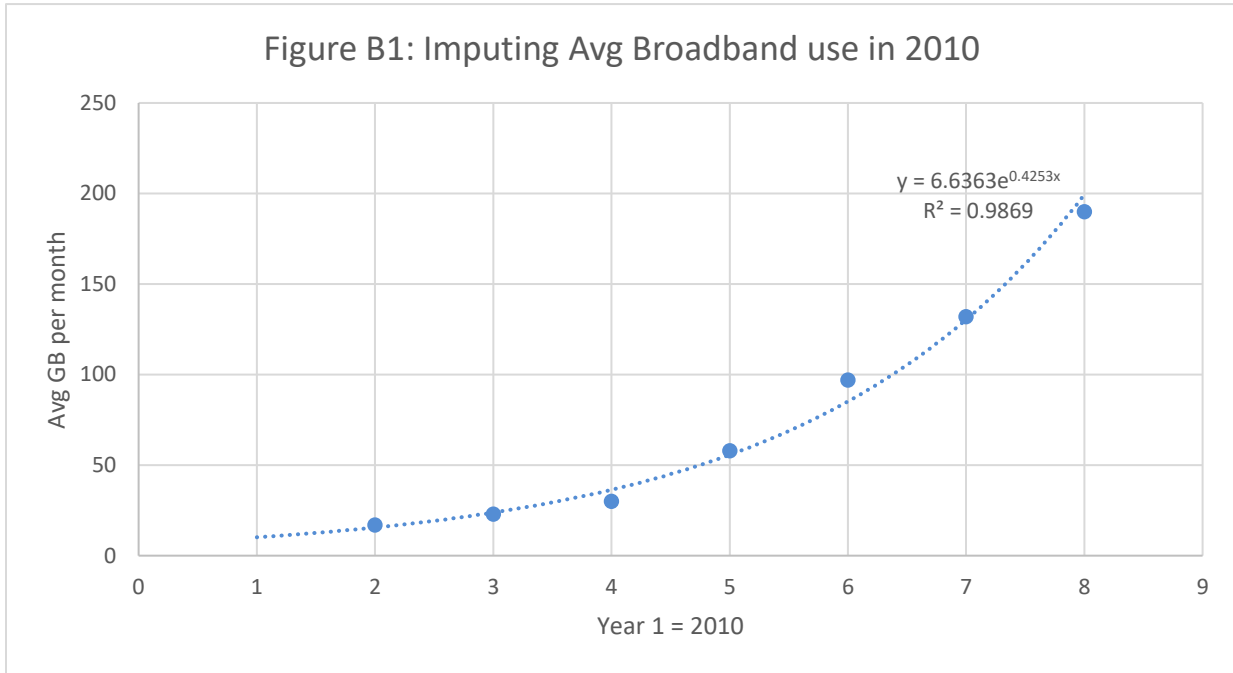*Assumption2: Each text message uses 140 bytes*

6. At present we do not distinguish between SMS and MMS. While we do not think that the volume of MMS would make a significant difference to our results, we will investigate this further.

Extrapolating missing values

7. The average fixed broadband and mobile data use data is only available for the period 2011-2017.

8. Since we are trying to construct a deflator for the period 2010-2017 we need to extrapolate the missing data points from the available data.

9. To do this, we fit an exponential trend line and project backwards (see Figures B1 and B2 below)

Assumption 3: Fixed and Mobile data use follows an exponential trend

Figure B1: Imputing Avg Broadband use in 2010

$y = 6.6363e^{0.4253x}$
$R^2 = 0.9869$

Avg GB per month

Year 1 = 2010

Figure B2: Imputing Mobile Data Use in 2010

$y = 49.459e^{0.4678x}$
$R^2 = 0.9815$

Annual PB Usage

Year 1 = 2010

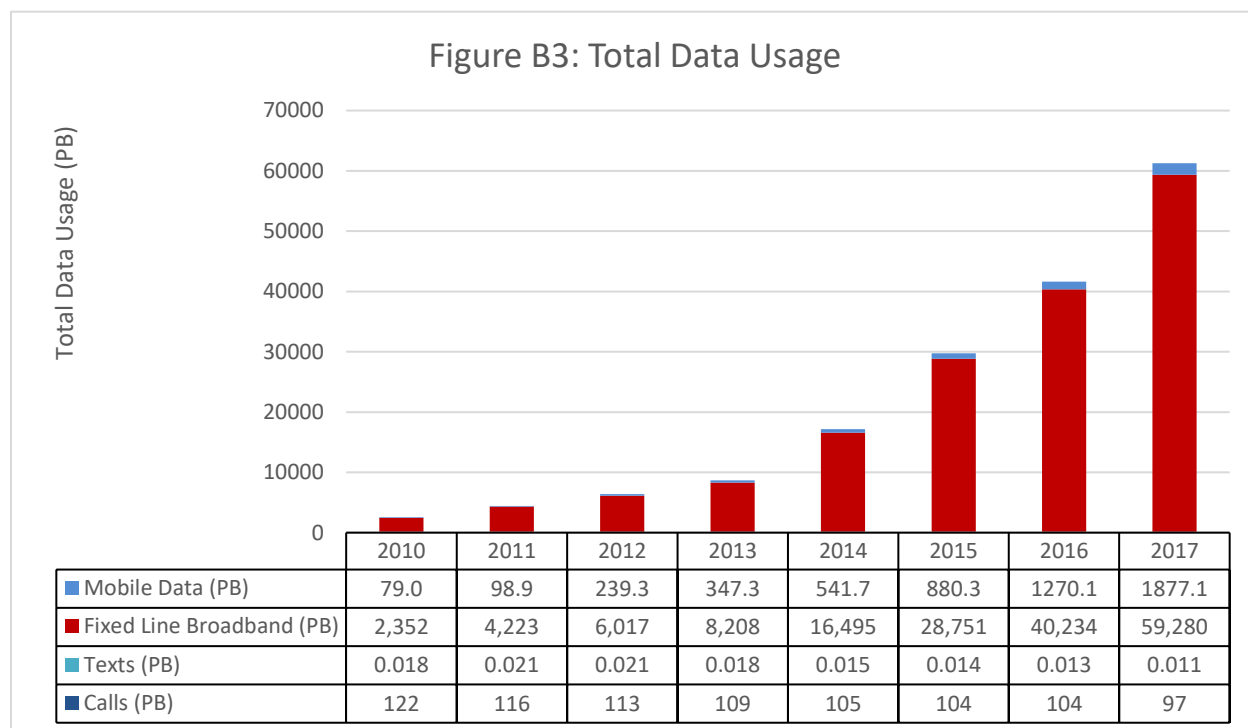**Imputing total fixed broadband and mobile data usage**

10. For fixed broadband usage, we only have the average fixed usage for a particular month in a year. We therefore have to make the simplifying assumption that the average for that particular month stays constant throughout the year

Assumption 4: The average broadband use for the given month is constant throughout the year

11. To impute the yearly fixed broadband use from the average monthly use, we multiply the monthly use with 12 and the number of fixed broadband lines.

12. While assumption 4 is not satisfactory, it gives us a good proxy for yearly fixed broadband data usage. We will investigate alternative data sources that can give us actual yearly broadband data usage.

13. To impute the yearly mobile data use from the average monthly use, we multiply the monthly use with 12 and the number of active mobile subscriptions (excluding Machine-to-Machine subscriptions)

Total data ussage

14. Figure B3 shows a breakdown of our estimated yearly data usage.

15. Almost all (or 99.8%) of the total data usage in 2017 is thereby estimated to come from fixed broadband (around 97%) and mobile data (around 3%).

16. Voice calls only contributed around 0.2% to the total data usage in 2017 (down from 5% in 2010), while text messages contributed only insignificantly to the total data volume since 2010.

Figure B3: Total Data Usage

Total Data Usage (PB)

	2010	2011	2012	2013	2014	2015	2016	2017
Mobile Data (PB)	79.0	98.9	239.3	347.3	541.7	880.3	1270.1	1877.1
Fixed Line Broadband (PB)	2,352	4,223	6,017	8,208	16,495	28,751	40,234	59,280
Texts (PB)	0.018	0.021	0.021	0.018	0.015	0.014	0.013	0.011
Calls (PB)	122	116	113	109	105	104	104	97

Total revenue breakdown

17. Figure B4 below shows a revenue breakdown for the Telecommunications industry. We include all revenue components in the calculation of our deflator, given our argument that all Telecoms services can be represented as data bits and bytes. [30]

Figure B4: Telecoms Revenue Breakdown
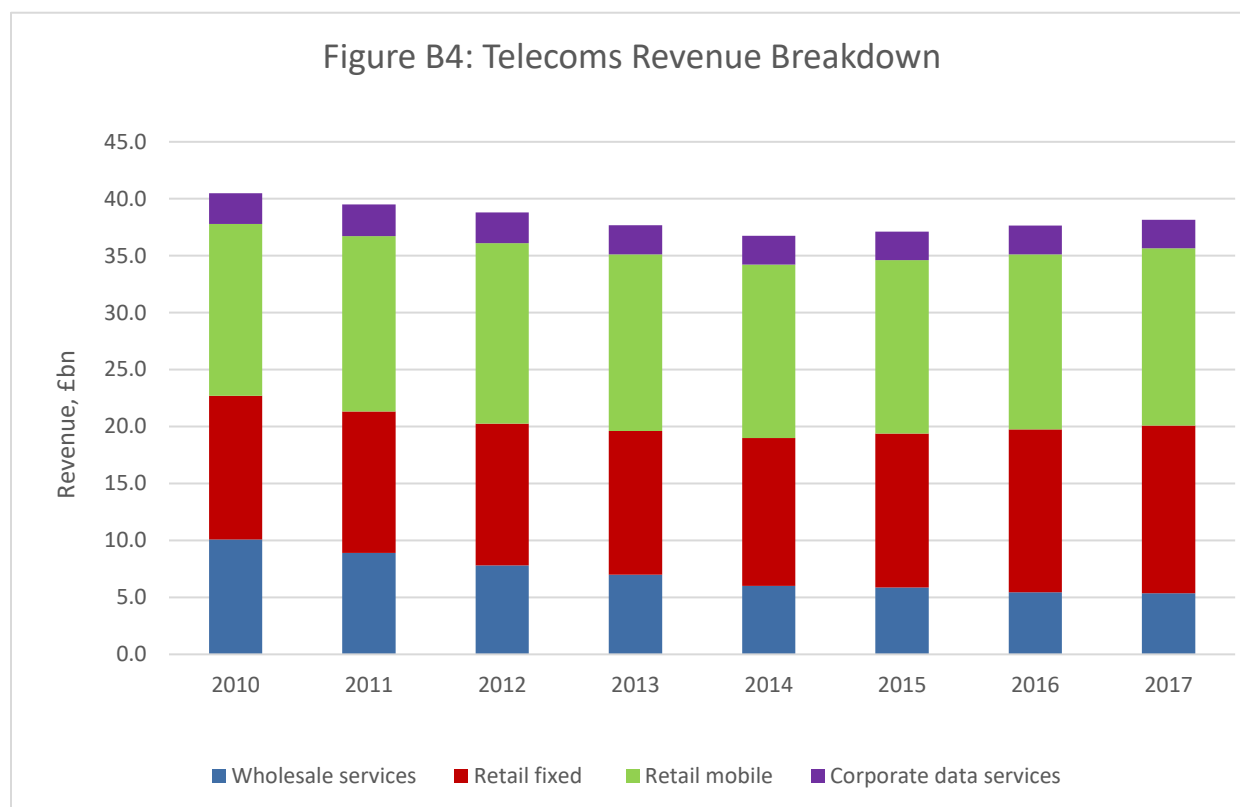
18. The revenue for corporate data services is estimated for 2017.

19. The following services are thereby included in the Corporate data and Wholesale components:

   a. Corporate data services:

      i. Web hosting

      ii. Ethernet

      iii. IP VPN

      iv. Digital Leased Lines

      v. Corporate VoIP

      vi. Frame relay/ATM services

   b. Wholesale mobile:

. . .

30. 1 byte = 8 bits

i. Wholesale mobile voice, text and data services

ii. Mobile voice and SMS termination revenue

iii. Wholesale inbound roaming revenue (i.e. revenue from overseas operators when their subscribers use UK networks)

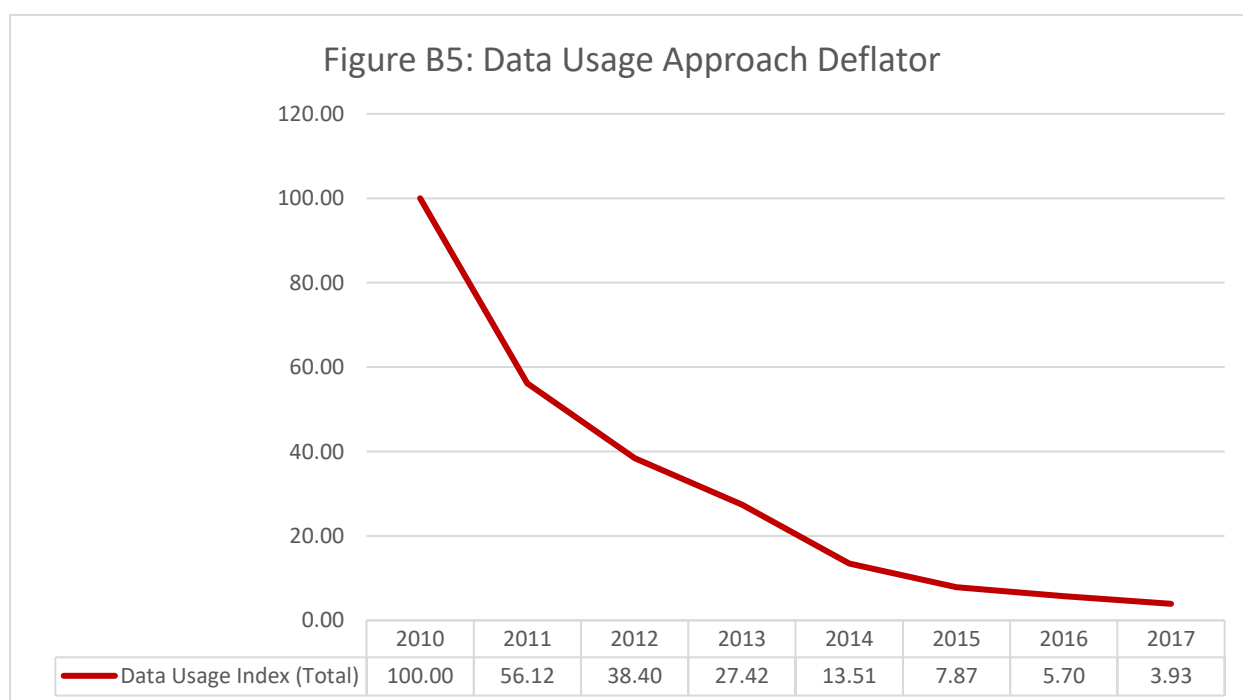**Average price and resulting deflator series**

20. We obtain our £/Mb measure by dividing Total Revenue by Total Data usage. This bundles many different contract arrangements together but is thus insensitive to rapidly-varying contract terms.

21. Table 1 below shows the average cost of data for different measurement units. Our estimates thereby suggest that the cost of data transfer has declined by around 96% between 2010 and 2017.

Table 1	2010	2011	2012	2013	2014	2015	2016	2017
£/PB	15,863,776	8,902,962	6,091,596	4,349,145	2,143,014	1,248,571	904,818	622,722
£/TB	15,864	8,903	6,092	4,349	2,143	1,249	905	623
£/GB	15.86	8.90	6.09	4.35	2.14	1.25	0.90	0.62
£/MB	0.016	0.009	0.006	0.004	0.002	0.001	0.001	0.001

22. Using the information in Table 1, we can then construct the deflator index for the data usage approach by evaluating the average price for each year as a proportion of the price in 2010 (our base year)

23. The resulting index can be seen in Figure B5 below.

Figure B5: Data Usage Approach Deflator

	2010	2011	2012	2013	2014	2015	2016	2017
Data Usage Index (Total)	100.00	56.12	38.40	27.42	13.51	7.87	5.70	3.93

ANNEX C: METHODOLOGY GUIDE TO THE IMPROVED SPPI

Data sources

1. We obtain our data from Ofcom's Telecommunications Market Data Tables and Communications Market Reports 2016, 2017 and 2018

2. From the Telecommunications Market Data Tables we obtain the following data series:

Fixed line telecommunication

    a. Summary of residential exchange line numbers at end of quarter by operator

    b. Summary of business exchange line numbers at end of quarter by operator

    c. Summary of residential network access & call revenues by operator

    d. Summary of business network access & call revenues by operator

    e. Summary of residential call volumes by call type and operator

    f. Summary of business call volumes by call type and operator

    g. Summary of residential call revenues by call type

    h. Summary of business call revenues by call type

Mobile telecommunication

    i. Call and message volumes by call type

    j. Estimated retail revenues generated by mobile telephony

3. From the Communications Market Report we obtain the following series:

    a. Summary of UK telecoms revenues

    b. Average fixed broadband data use

    c. Average mobile data usage

   d. Active number of mobile subscriptions (excluding Machine-to-Machine)

Constructing the deflator

Aggregation structure

4. Just like the current SPPI, we construct granular unit value indices for the new SPPI and aggregate them together using revenue weights

5. The major difference to the current SPPI is that the improved SPPI:

    a. Includes Broadband and Mobile Data

    b. Includes Business and Consumer transactions

    c. Has annually updated weights

6. Figure C1 shows the Aggregation Structure of the improved SPPI

Figure C1: Aggregation structure for improved SPPI
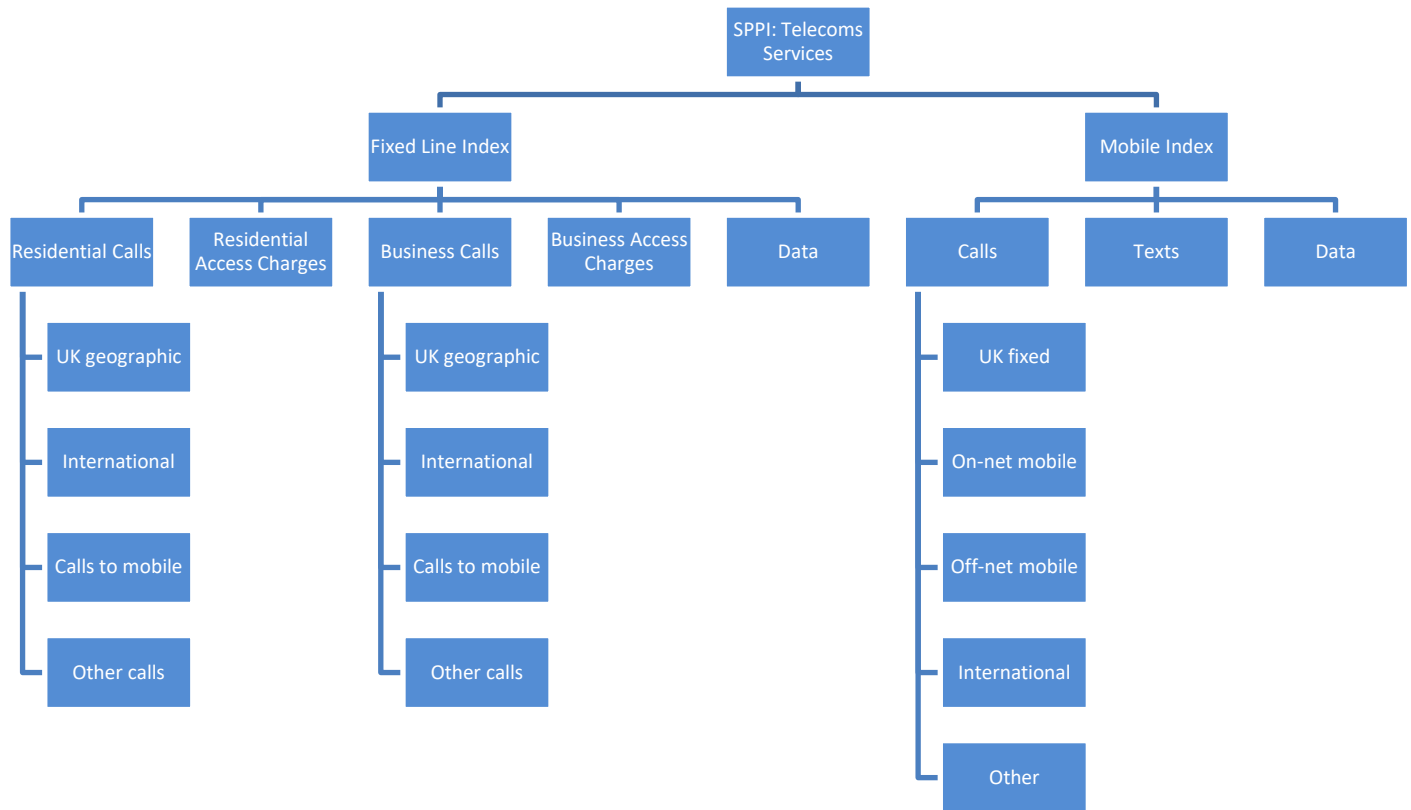
Fixed line index

7. This index includes call charges for different call types and access charges. These are split between charges for residential and business users.

8. For call charges, we have volumes (in millions of minutes) and revenues (in £m) at the desired granularity and so the calculation of unit values for these is straight forward

9. For access charges, it is difficult to define the volume. While the volume of calls and data is relatively straightforward, access charges are essentially a gateway payment; providing access to all the telecommunication services. This however, means that a corresponding volume to get unit values is much more difficult to define. Ideally the volume should be related to the benefit derived, which in this case means the calls and data, using their respective volume shares to account for how much they account for the benefit received. However, volumes of calls (minutes) and data (bits) cannot be compared without converting minutes into data as is done with the Data Usage based approach. However, one of underlying reasons for using the improved SPPI is that Voice and Data (as well as Texts) are heterogeneous products and should not be converted into bits of data transported. We therefore use the number of subscribers as the volume. This means that the volume is not directly linked to the benefits derived from the payments.

10. The Fixed Line Index also includes charges for data services. The construction of the unit values for data services follows the same approach as the data usage approach. While we have data services revenue for all years, we are missing the data volume for 2010. We extrapolate the data volume for 2010 following the same approach as in the data usage approach. See Annex B, paragraphs 7-13 for details.

Mobile index

11. This index includes charges for calls, texts and data. These are thereby split into Bundled and Out-of-Bundle Charges.

12. The volumes for mobile data are only available for the years 2011-2017. We impute the missing values for 2010 following the same approach as the data usage approach. See Annex B, paragraphs 7-13.

13. One of the problems with constructing the Mobile Index is the volume and revenue are not available for the same level of granularity.

14. For volume, we have total volumes broken down by service types (calls, texts and data). The call volumes are further broken down by call type.

15. For revenue, only the out of bundle revenues are available to the desired granularity. For bundled revenue we only have a single (aggregate) figure that is not broken down by service type.

16. To overcome this problem, we impute values for revenue and volume to get both to the desired level of granularity.

17. To impute a breakdown for bundled revenues, we assume that the different services types have the same share in the bundled revenue as they have in the out of bundle revenue, see Figure C2.

Assumption 1: The revenue weights of the different services in the bundled revenue are the same as the revenue weights in the out of bundle revenue.
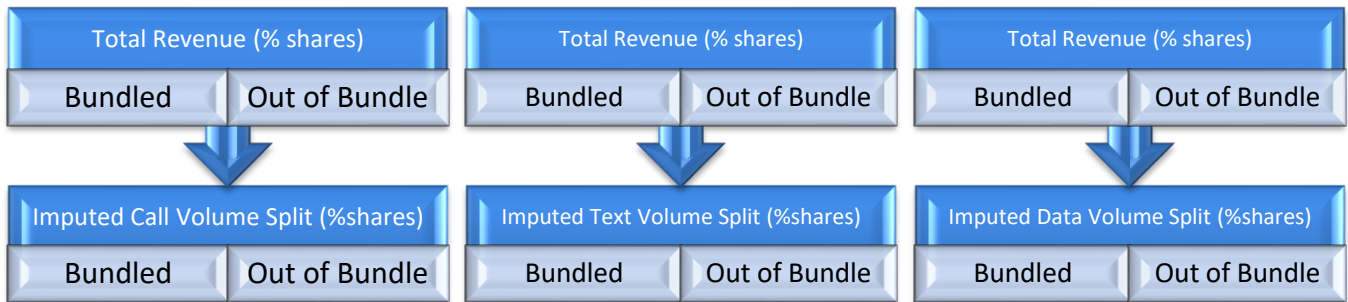
Figure C2: Imputing breakdown for bundled revenue
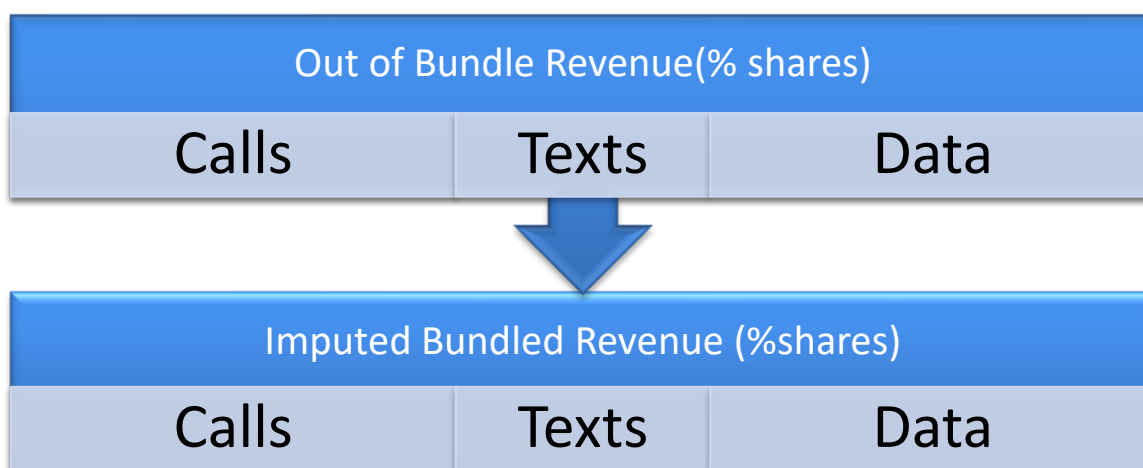
18. Since we only have total volume figures, we have to impute bundled and out of bundled volumes. In this case, we assume that the proportion of Bundled and Out Of Bundle Volume follows that of the overall Bundled/Out of Bundle Revenue Split

Assumption 2: The bundle/out of bundle split for each service volume is equal to the split in the total revenue

Figure C3: Imputing volume splits

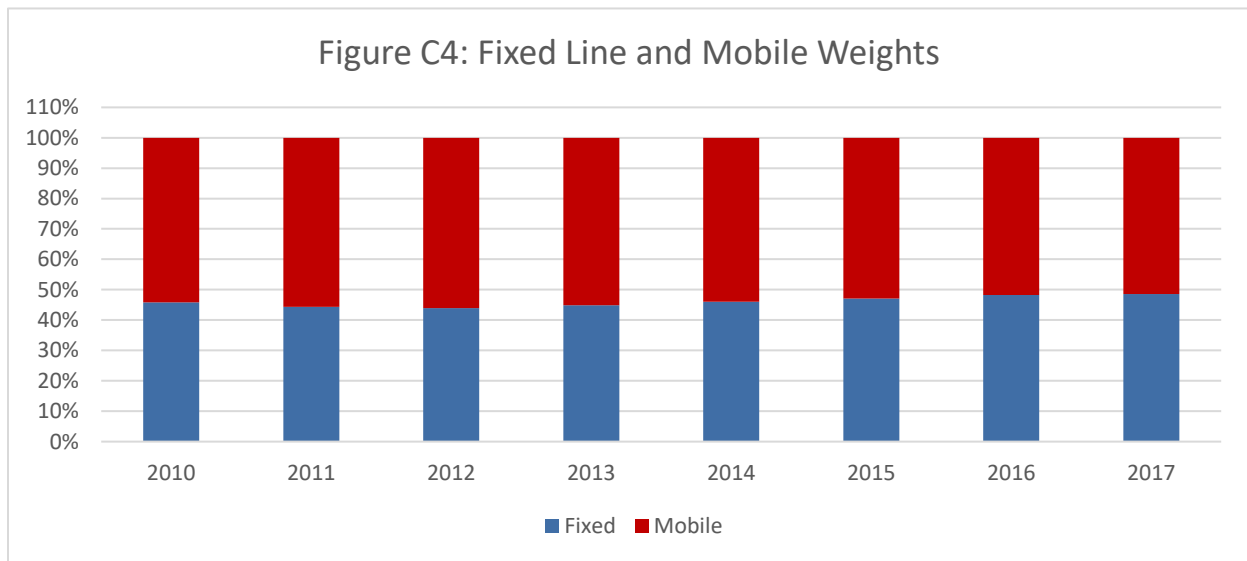| Total Revenue (% shares)		Total Revenue (% shares)		Total Revenue (% shares)	
Bundled	Out of Bundle	Bundled	Out of Bundle	Bundled	Out of Bundle
Imputed Call Volume Split (%shares)		Imputed Text Volume Split (%shares)		Imputed Data Volume Split (%shares)	
Bundled	Out of Bundle	Bundled	Out of Bundle	Bundled	Out of Bundle

19. All unit values are then calculated on a bundled and out of bundled charge basis. These are then aggregated up to a Bundled and Out of Bundle Mobile Indices using revenue weights.
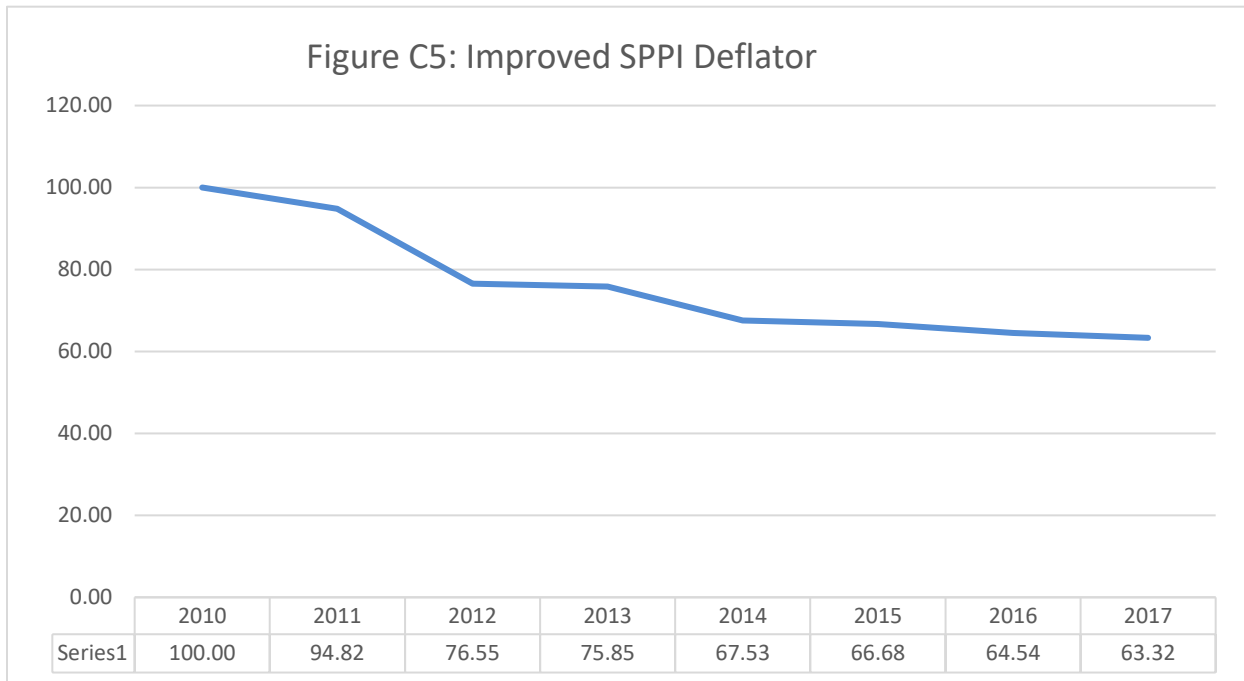
20. Finally we aggregate the Bundled and Out of Bundle Mobile Indices using revenue weights to get an overall Mobile Index as shown in Figure C3.

Overall index

21. To get an overall index for the improved SPPI we aggregate the Fixed Line and Mobile Indices using revenue weights. Figure C4 shows the weights used to aggregate the Fixed Line and Mobile Indices into the overall SPPI. The revenue split between mobile and fixed line is thereby roughly equal

Figure C4: Fixed Line and Mobile Weights

22. Figure C5 shows the overall improved SPPI series.

Figure C5: Improved SPPI Deflator

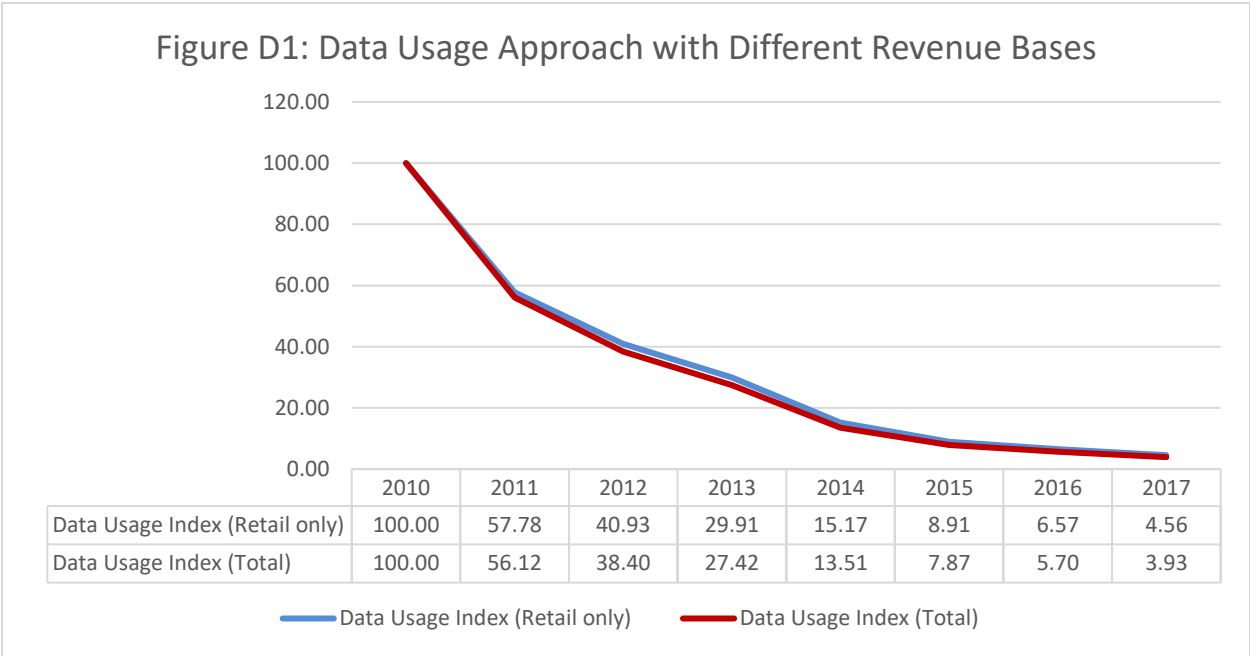|	2010	2011	2012	2013	2014	2015	2016	2017
Series1	100.00	94.82	76.55	75.85	67.53	66.68	64.54	63.32

ANNEX D: DATA USAGE APPROACH USING RETAIL REVENUES ONLY

Some of the volume data for the data usage approach is limited to retail volumes. Whilst we capture revenue from wholesale and corporate data services, the corresponding volumes are more difficult to identify.

Corporate Data Services for example are often delivered through digital lease lines and the volume of usage is often not measured. Likewise, wholesale volumes, i.e. services that telecoms services providers buy from each other, often have different billing arrangements from the retail market and the volumes are not always readily available.

However, this limitation does not have a substantial impact on our results. Figure D1 below compares the data usage approach that we use in the paper to an adjusted deflator that only uses retail revenues. As the figure shows, there is only a minimal difference between the two indices, with the retail only version of the data usage approach being 1-2.5 index points higher. The reason for this is that, while the retail revenues constitute the bulk of telecommunications services revenue, wholesale revenues have been declining at a much faster rate. The inclusion of wholesale and corporate revenues could however bias our results if their corresponding volumes have a significantly different trend from the retail volumes. Further work is therefore required to ascertain these trends and identify suitable datasets for wholesale and corporate data volumes.

Figure D1: Data Usage Approach with Different Revenue Bases

	2010	2011	2012	2013	2014	2015	2016	2017
Data Usage Index (Retail only)	100.00	57.78	40.93	29.91	15.17	8.91	6.57	4.56
Data Usage Index (Total)	100.00	56.12	38.40	27.42	13.51	7.87	5.70	3.93

— Data Usage Index (Retail only) — Data Usage Index (Total)

REFERENCES

Adelman, Irma, and Griliches, Zvi. 1961. "On An Index of Quality Change."*Journal of the American Statistical Association*, Vol. 56, No. 295, pp.535-548

Ahmad, Nadim, Ribarsky, Jennifer, and Marshall, Reinsdorf. 2017. "Can potential mismeasurement of the digital economy explain the post-crisis slowdown in GDP and productivity growth?" *OECD Statistics Working Papers,* 2017/09

Bean, Charles. 2016. "Independent Review of UK Economic Statistics". Available at:
https://www.gov.uk/government/publications/independent-review-of-uk-economic-statistics-final-report

Boskin Commission, 1996, *Final Report of the Commission to Study The Consumer Price Index*,
https://www.finance.senate.gov/imo/media/doc/Prt104-72.pdf

Byrne, David, and Corrado, Carol. 2017. "ICT Prices and ICT Services: What do they tell us about Productivity and Technology?" *Finance and Economics Discussion Series* 2017-015. Washington: Board of Governors of the Federal Reserve System

Coyle, Diane. 2017. "Do-it-yourself digital: Searching for clues to solve the productivity puzzle". Economic Statistics Centre of Excellence Discussion Paper Number 2017-1. Available at https://www.escoe.ac.uk/wp-content/uploads/2017/02/ESCoE-DP-2017-01.pdf

Diewert, W Erwin. 1998. "Index Number Issues in the Consumer Price Index." *Journal of Economic Perspectives,* 12(1): 47-58. DOI: 10.1257/jep.12.1.47

Ellis, AD, Suibhne, NM, Saad, D, Payne, DN. 2016. "Communication Networks Beyond the Capacity Crunch."*Philosophical Transactions of the Royal Society* A374: 20150191. http://dx.doi.org/10.1098/rsta.2015.0191

Feldstein, Martin. 2017. "Underestimating the Real Growth of GDP, Personal Income, and Productivity." *Journal of Economic Perspectives* 31(2): 145-164.

Greenstein, Shane, and McDevitt, Ryan. 2010. "Evidence of a Modest Price Decline in US Broadband Services." *NBER Working Papers* 16166, National Bureau of Economic Research.

Griliches, Zvi, and Cockburn, Ian. 1993. "Generics and New Goods in Pharmaceutical Price Indexes." *NBER Working Papers* 4272, National Bureau of Economic Research.

Griliches, Zvi. 1961. "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change." *The Price Statistics of the Federal Governement*, pp. 173-196. National Bureau of Economic Research.

Griliches, Zvi. 1994. "Productivity, R&D, and the Data Constraint." *American Economic Review* 84(1): 1-23.

Groshen, Erica, Moyer, Brian, Aizcorbe, Ralph B., Friedman, David M. 2017. "How Government Statistics Adjust for Potential Biases from Quality Change and New Goods in an Age of Digital Technologies: A View from the Trenches." *Journal of Economic Perspectives* 31(2): 187-210

Heys, Richard, and Awano, Gaganan. 2016. "Measuring output in the Information Communication and Telecommunications industries", ONS, Available at:
https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/articles/measuringoutputintheinformationcommunicationandtelecommunicationsindustries/2016

Hausman, Jerry. 1996. "The Valuation of New Goods under Perfect and Imperfect Competition", pp207-248 in eds Timothy F. Bresnahan and Robert J. Gordon, *The Economics of New Goods,* NBER, http://www.nber.org/chapters/c6068.pdf

Hausman, Jerry A. 2003. "Sources of Bias and Solutions to Bias in the Consumer Price Index." *Journal of Economic Perspectives* 17(1): 23-44.

Hicks, John. 1940. "The Valuation of Social Income", *Economica*

Nordhaus, William D. 1994. "Do Real Output and Real Wage Measures Capture Reality? The History of Lighting Suggests Not." *Cowles Foundation Discussion Papers* 1078, Cowles Foundation for Research in Economics.

Nordhaus, William. 2007. "Two Centuries of Productivity Growth in Computing." *The Journal of Economic History, 67*(1), 128-159. doi:10.1017/S0022050707000058Updated 2010 appendix available at www.econ.yale.edu/~nordhaus/homepage/

Office for National Statistics (2018) 'Division level labour productivity estimates: February 2018'. ONS, Available at
https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/articles/divisionlevellabourproductivityestimates/january2018#the-effect-of-reallocation-on-output-per-hour-growth

ONS (2018a): 'Economic Statistics and Analysis Strategy'. Available at www.ons.gov.uk/esas

Stapleford, Thomas A. 2009. "The Cost of Living in America". Cambridge University Press.

Williams, Brendan. 2008. "A Hedonic Model for Internet Access Service in the Consumer Price Index." *Monthly Labor Review*, July.

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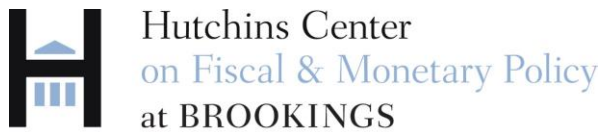
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