

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-recognised issues, 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 issues particularly affect high-tech and digital products where engineering progress has been rapid over the last twenty years, and in which high rises in usage have been accompanied by large drops in unit price. This has led to some suggestion that the official deflators understate ‘true’ declines in the price of such products and that the real growth of the digital economy may therefore be understated. This has been debated in research and also official reports, such as Bean (2016).

This paper explores these issues with respect to telecommunications services output, as the industry has experienced all these challenges. This work was carried out jointly by economists and engineers².

As we show below, there has been an exponential growth in the quantity of data transmitted via telecommunications networks (both fibre and wireless) in recent years. Intuitively, this huge gain in achieved data transmission performance at the same or declining cost should represent a significant gain in output, irrespective of the content transmitted by the data, or the price charged for this content. This paper does not venture into 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 within the National Accounts and what difference options around the calculation of deflators would make to their measurement. We primarily review an update of the current methodology and an alternative data usage driven approach. These provide a range of estimates which vary

² We thank the following working group members for their invaluable contributions: Ahmed Kotb (IET), Anna Ardanaz-Badia (ONS), Ash Loakes (ONS), Chris Payne (ONS), Daniele Viappiani (HMT), David Mark Harrison (Ofcom), Emma Howley (ONS), Frances Cairncross (Oxford University), Gaganan Awano (ONS), Gary Clemo (Ofcom), Hannah Conway (IET), Hannah Evans (ONS), Helen Sands (ONS), James Scruton (ONS), Jeremy Watson (IET), John Jeremy (ONS), Jonathan Haskel (Imperial College), Jonathan Porter (Ofcom), Kat Pegler (ONS), Marilyn Thomas (ONS), Mark Stephens (ONS), Marko Melolinna (Bank of England), Max Fernando (Ofcom), Miles Elsdon (Massive Dynamics), Monique Sidhu (ONS), Nicolas Oulton (LSE/Centre for Macroeconomics), Nigel Brown (Cabinet Office), Peter Goodridge (Imperial College), Peter Ladkin (Causalis), Robert Kent-Smith (ONS), Stephanie Baxter (IET), Sanjiv Mahajan (ONS), Thomas Lewis (ONS), Tim Miller (Plum Consulting), Tony Lavender (Plum Consulting)

considerably, so we also look to the degree competition and technological change in the sector may lead to convergence between our options in time.³

Convergence depends on whether these two options are actually alternatives or whether convergence in the price per unit of data charged currently for different communications services is to be expected, primarily through competition between differently priced close substitutes: where these charge customers a different price per unit of data this should ultimately lead to the lower cost substitute becoming dominant and winning market share, causing convergence between the two, as long as there is enough competition in the market. Convergence would make a data usage driven unit value index a more meaningful proxy deflator. We present evidence that some convergence is under way, though not yet enough to ‘correct’ the perceived measurement issue.

The two options discussed explore the 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 fall in cost per bit of data through time.

Our first option here presents a relatively cautious updating of the current deflator in line with current international norms and standards to deliver a more exhaustive deflator which addresses key current weaknesses, 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 measurement of the volume of data and then uses the revenue per unit of data as the deflator.

The results are striking. Both approaches suggest substantially faster paces of decline than the present deflator. We find that real prices of telecommunications services could be 35 – 90 percentage points lower than the current deflator suggests. This implies that the real growth of telecommunications services in the National Accounts has been understated. Both of these are, in their own way extreme values which deliver a wide spectrum of possibilities, so we present some potential amendments to our two approaches which may help us tighten this range.

³ In 2016 the Office for National Statistics (ONS) came together with leading academics and the Institution of Engineering and Technology (IET) to review this issue from their different perspectives to identify potential solutions and new data-sources. A previous ONS article (Heys & Awano (2016)) outlined some of the key conceptual issues in scope across this agenda.

The rest of this paper is structured as follows: First, we provide some context to this paper, including its scope, theoretical issues underpinning price indices and a brief overview of the literature in this field. We then discuss engineering issues in terms of the differences between the various telecommunication services and how we can represent the output of all services in terms of bits transported. Following this, we present the methodology of the current deflator, along with two alternative options and discuss their strength and weaknesses. Finally, we present and discuss the results of this paper and its limitations.

CONTEXT

Scope of this paper

There are three ways of calculating GDP: Output, Expenditure and Income. In theory, these three methods should yield equal results but in practice they often differ. This is due to the fact that different data sources are used in their construction. To ensure that the three approaches yield the same estimates, National Accountants use a balancing process.

Whilst the different approaches to estimating GDP use different deflators, this paper only concerns the output approach and the deflation of telecommunication services therein. Telecommunication services thereby comprise four sub-categories in the International System of Industrial Classification of All Economic Activities (ISIC) 2008 system:

- 6110 Wired telecommunications activities
- 6120 Wireless telecommunications activities
- 6130 Satellite telecommunications activities
- 6190 Other telecommunications activities

Price Indices in Light of Quality Changes and New Goods

There are no new problems in National Accounts, only old problems re-surfacing in fresh forms. The questions concerning measurement of the digital economy which have surfaced over recent years often re-open older debates. When focussing within this on the telecommunication services industry, of particular relevance is the extensive literature on price indices. One of the defining characteristics of modern economic growth is the prevalence of innovation, either as new products and services, improved quality and variety, or in terms of business model innovations (such as discount supermarkets rather than corner groceries). This 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 bias⁴. Statistical offices sometimes use unit value indices for pragmatic reasons but economic theory is not on their side, and turns to 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 change⁵.

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

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.

Laspeyres (or Lowe⁶) index is therefore often used in practice, (either with fixed weights or annually updated weights).

Given standard practice, there are several ways of reducing the potential bias, employed to differing degrees by statistical offices since these issues were debated in the literature, particularly after the Boskin Commission Report. 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 key 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 are seen as bundles of more fundamental characteristics. Hedonic adjustment is typically applied to a few goods experiencing rapid change in their quality or characteristics, accounting for a small proportion of the consumption basket (0.39 % in the UK⁸), in part because of the significant data requirements. 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.

Literature Review

There is an extensive literature considering both the new goods problem and the hedonics 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 that were popularised by Griliches (1961). Williams (2008) studies 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 the bandwidth. Williams finds that quality adjusting the price index for internet access makes little difference. Greenstein and McDevitt (2010), on the other hand, find that quality adjusting the broadband price index does make a difference, but they only find moderate price differences compared to the official measures. The authors use a sample of over 1,500 price quotes for the period 2004 to 2009 that they obtain from a private consultancy. They use this to construct a hedonic model where the main quality

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)

⁸ This figure relates to the Consumer Price Index

characteristic is the download and upload speed. They find that quality adjusted prices fell by around 3%-10% in the studied period. This was a steeper decline than the official measure but still significantly lower than the quality adjusted price changes for other products such as computers.

While the above results may be surprising, they also raise questions about the limitation of hedonic studies. For one, there is a question about the completeness of product characteristics used in the hedonic regression. Bandwidth, while an important product characteristic, is not sufficient to explain price and quality changes of broadband. Other factors such as data caps, speed limitations at peak times, latency (round-trip delay) and coverage are important quality considerations of the broadband itself, and there is the 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. 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. Also, actual bandwidth cannot be captured in hedonic functions as the actual speeds cannot be observed on an individual service contract level. Secondly, it is difficult to construct representative baskets of broadband service contracts, given the complexity of pricing in the industry and the sheer 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 of the limitations of hedonic regressions in general. The author argues that prices in imperfectly competitive markets are determined by demand, cost and the degree of competition in the market and that hedonic regression 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 to run the regression. This is especially relevant for products 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 the 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 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 volume⁹. Griliches and Cockburn (1993) study the prices of generic drugs in more detail and test out 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 method used in the official statistics.

Price indices, even hedonically adjusted, will 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 value of the service characteristic directly. This approach has been applied to lighting (lumen hours) and computer processing (computations per second) by William Nordhaus (1994, 2007), who constructed careful 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. In telecoms, a key question addressed in this paper is whether a reliable service characteristic – bits of data transported – can be measured in a way which is conceptual and computational useful.

Both alternatives to hedonics indicate substantial upward bias in conventional price indices. Both involve painstaking statistical and econometric work and are not practicable for the regular calculation of official price indices.

In short, 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

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

innovation.

This issue remains a live and actively debated one, see, for example Bean (2016), and the work in the US, such as Byrne & Corrado (2017) and Groshen et al (2017). Ahmad, Ribarsky & Reinsdorf (2017) attempt international comparative work to try to gauge the scale of the problem by applying different countries deflators to other countries and seeing if the magnitude of the resultant volume change is large enough to merit further work, finding that the impacts are relatively small. The weakness of this approach is, as we argue in this paper, comparing the impact of a variety of upwardly biased deflators is not the same as the impact of a more correctly specified deflator, which we attempt in this paper.

ENGINEERING ISSUES

The key question considered in this paper 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 covers both the appropriate units of measurement, and how to conceptualise quality.

Data and its characteristics from the engineering perspective

Users primarily buy digital products and services of many kinds, from movies to banking services, rather than buying their transport. However, in engineering terms communications, be it of traditional telephony, TV/video, banking or social/text networking, is essentially a bit-transport service, in the same way 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. The user pays directly or indirectly for both the transport and for the service being transported. Data services in the UK are provided either via fibred or wireless connections.

The cost of a fibre network is typically dominated by the fixed costs of installation¹⁰, and this has not changed very much in recent times. However, the data rate achieved on an installed single fibre has risen by some 10^{10} times (from 0.1MBit/s to 1 PetaBit/s) for champion results¹¹ between 1960 and 2015. Similarly the data rate for widely installed systems has risen 10^6 times between 1980 and 2015 (from about 1Mbit/s to about 1Terabit/s).¹² These improvements each broadly equate to a fairly steady log growth

¹⁰ Meaning civil engineering (construction) for the most part.

¹¹ Champion results are those achieved in best case experimental systems. See Ellis et al (2016)

¹² 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

gradient of 150% per annum or 5000-6000% per decade¹³. Although there has been some levelling off in the 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.

Nevertheless in most cases users do clearly understand that the transport is necessary and would expect to pay for this. For ordinary physical products they would expect that any transport necessary would cost an amount relating to transport-specific characteristics such as the product's size and weight, not to the intrinsic value of the product itself (with some exceptions).¹⁴

Key within this debate are the conversion rates of different products into bits or bytes of data. 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 following conversions 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

There are a number of simplifying assumptions made here:

- For text, we ignore shorter/longer messages and 'emoticons' for simplicity and assume all texts are 140 characters long, particularly as 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.

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.

¹³ Interestingly similar to Moore's Law

¹⁴ A lorry capable of carrying one ton of goods will cost the equivalent amount, and consume similar quantities of petrol whether it carries one ton of gold, or fish, or steel, or paper.

- Similar arguments apply to picture and movie compression, which will depend upon the characteristics of the particular images involved, and will also likely change over time with technical developments. But these differences tend to look modest compared to the scales involved, and are in any case a further argument for sticking with the bits as a more stable measure.

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 – 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 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. 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. It is also the case that telephony and texting are subject to different charging models than internet-based data services. This means there are significant price differences for similar services, particularly when converted into a 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

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

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

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.

- How long will different products as seen by the user (telephony, texting, data usage), all of which are essentially end-presentations of the same product (data), continue to be regarded as different?
- How long will price differentials exist for these products?
- As cheaper substitutes are produced, how long will providers continue to deliver these services in the old mode – how long will telephony providers deliver telephony distinct from data or port across to using a Skype-type technology which delivers the same user service, but uses less data and therefore occurs at lower cost?
- Is it therefore appropriate or not to consider, for example, Skype or telephony as substitutes?

It is likely that the kind of service people will use on their devices, fixed or mobile, will continue to shift rapidly in ways that we generally find hard to predict.

METHODOLOGIES

Here we discuss the current method for constructing an output deflator for telecommunication services and two alternative options. The first new option is an improved Services Producer Price Index (SPPI), which nevertheless uses the same unit value index methodology. The other, in response to the questions immediately above, is an alternative unit value index based on data usage. In assuming perfect substitutability, the unit value changes in the data usage approach would in theory reflect pure cost-based changes. Given the caveats about the assumption, it should be interpreted as a downward biased approximation to the change in prices that would keep consumer welfare constant. Our two alternative options can therefore be considered respectively as an upward and downward biased approximation to some theoretical and as yet undeveloped utility-based hedonically-adjusted superlative index.

The current SPPI treats voice, and text as distinct services. Adding data into the basket on the same basis presents one route for improving this deflator. Option A, described below presents how we implemented this approach, its strengths and weaknesses. Option B presents an alternative which treat all data as equivalent, and creates a new unit value index, based on the price per unit of data. Again, the following section outlines key strengths and weaknesses.

Current Method

In the UK, the Office for National Statistics (ONS) currently deflates telecommunications services output at the domestic aggregate level¹⁷ using an index which is comprised of two components; the product level index of the Consumer Price Index (CPI) covering Telecommunications Services and Equipment and the product level index of the SPPI covering Telecommunications Services. These are currently weighted around two-thirds CPI and one-third SPPI in the creation of the deflator.

Figure A shows the overall deflator used in the UK.

Figure A: UK Telecommunications deflator

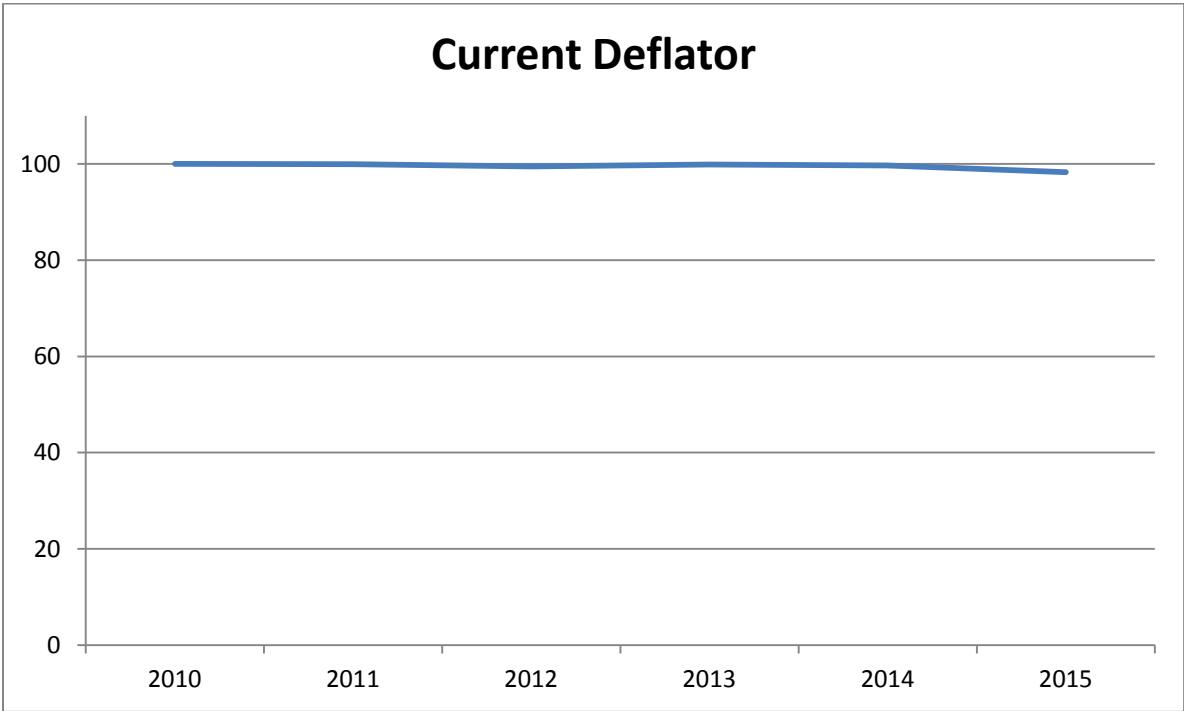
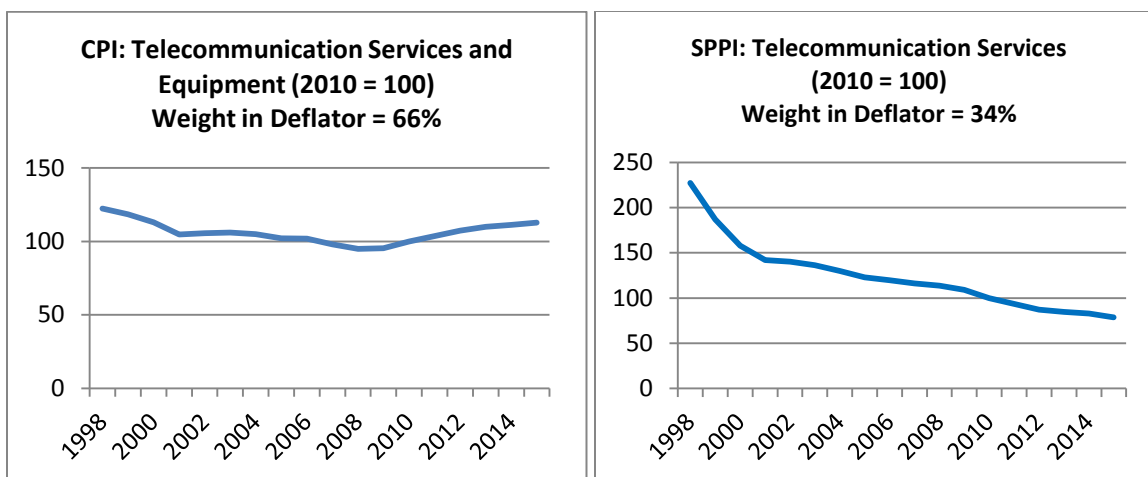


Figure B shows the movement of the different component indices between 1998 and 2015. While the SPPI shows a general downward trend, the CPI declines until around 2008 and then starts to increase again. Since CPI is more heavily weighted in the output deflator, the overall impact is that over recent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

¹⁷ Import and exports are treated separately.

Figure B: Components of GDP(O) Deflator in the UK



Whilst this approach meets international requirements, it is a methodology that is subject to a number of challenges borne out of pragmatic decisions necessary to deliver an appropriate deflator for the transactional relationship of interest, which is the sale of telecommunications services to businesses and consumers in the UK. These are:

1. The shares between CPI (reflecting business-to-consumer sales) and SPPI (reflecting business-to-business sales) reflects broad patterns in the UK economy, but may not be reflective at the product level.
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 purchaser's prices. These include wholesale and retail margins and costs and do not strictly map to the price which is of interest; the basic price of telecommunications services producers before logistics, retail and margins¹⁸.
3. The CPI product level index captures both goods and services, despite the product group to be deflated only including services. The CPI and the product group that is deflated are also classified using different systems that do not easily map¹⁹. This compromise is taken pragmatically to deliver the most accurate feasible deflator but may introduce potential biases in the values produced.

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.

4. Many of the CPI item level²⁰ indices are constructed using the traditional ‘basket of goods’ approach. 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” approach which is recommended by Eurostat²¹. The ONS thereby obtains representative consumer profiles from the UK’s telecommunications regulator, the Office of Communications (Ofcom). For each consumer profile, the ONS then 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 using new technologies are missed, even if most people are using the new technology. It should be noted that even when we were able to construct a representative basket of tariffs, 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 missed since these cannot be determined on an individual tariff basis as they are dependent on network and geographical region. As a result, actual quality changes might not be reflected in the price index, even when using hedonic adjustments.
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 key weakness.
6. There are methodological differences in the way that the 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, mainly using a ‘Basket of Goods’, as described above, the SPPI: Telecoms Services is a unit value index. The ONS

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.

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>

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 this sector. A notable absence, for example, from the SPPI is mobile and broadband data.

Irrespective of the eventual decision around the two options we present in this paper, the ONS is committed to reviewing and addressing this deflator in some form, stimulated both by these issues and the pertinence of the digital agenda, but also by mandated changes through the implementation of the European Union's Framework Regulation Integrating Business Statistics (FRIBS) regulation. Key within the FRIBS agenda is 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 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.

Option A: Exclusively Using An Improved SPPI

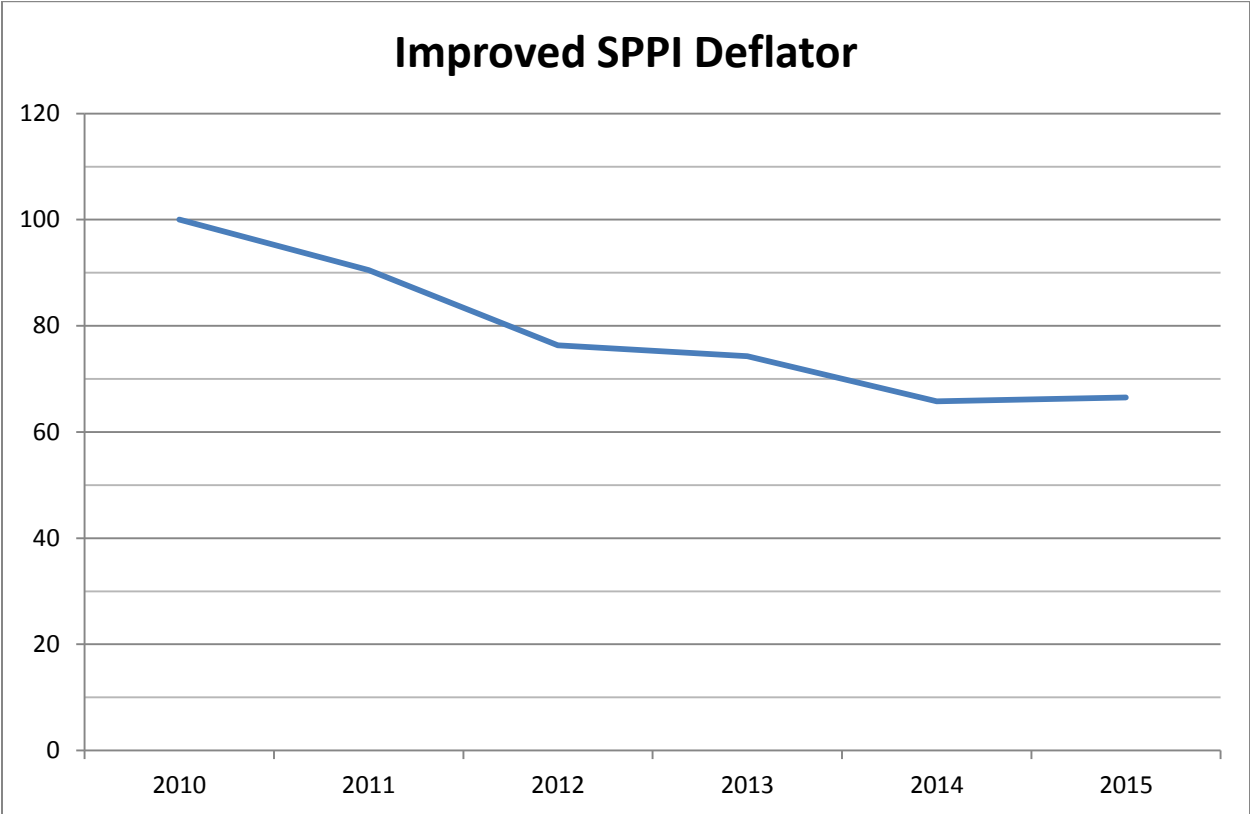
Under this option we would add broadband and mobile data to voice and text in the current SPPI. To reflect the potentially large difference in consumer values, we construct granular unit values indices and aggregate them together using revenue weights. This is largely based on the current SPPI with the major differences being that this 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 as a sole deflator delivers estimates that telecommunications services prices have declined by almost 35% between 2010 and 2015, see Figure C.

This method presents key benefits, in that it is strongly 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 avoids potential pitfalls if the different telecoms services are heterogeneous products.

However, the key weakness of this deflator is that it does not seem to reflect the significant technical and quality improvements in the industry. This is due to the fact that

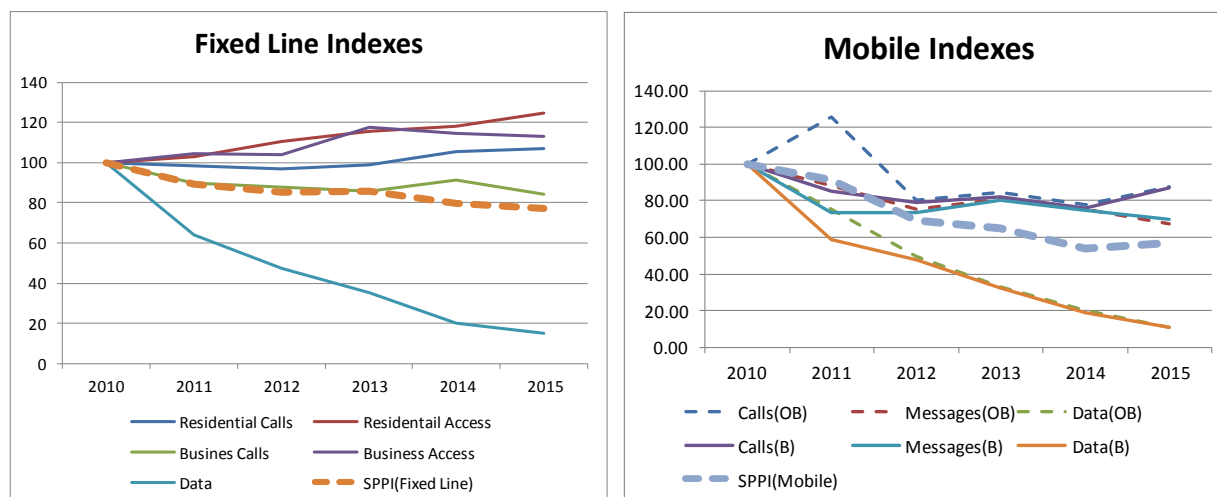
the deflator uses revenue weights and therefore underweights data services, which is the area that is driving technical progress in the industry. Between 2014 and 2015 for example, this deflator suggests that telecommunications services prices increased by around 1%. However, this period also saw a significant shift from 3G to more expensive 4G tariffs in the UK which was a significant quality improvement.

Figure C: Improved SPPI deflator



The switch from 3G to 4G tariffs after 2014 should have been reflected in a volume, rather than price increase, as it represents a quality improvement. However, the quality improvement mainly relates to the data element, for example through an increase in network speed. More generally, 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, see Figure D. The data items thereby show substantial price decreases. However, they have lower weights and thus only have a limited impact on the overall SPPI index.

Figure D: Breakdown of Improved SPPI Deflator²³



A special case in the construction of 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. The reasons behind the increase in access charges are different for residential and business subscribers. For residential subscribers, the price for line rentals has increased much faster than the number of subscribers. For businesses, the number of subscribers declined substantially. However, 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 it currently places a lower weight on the contributions of broadband and mobile data. This is due to substantial pricing 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 thereby has a limited impact on the deflator, whereas substitution away from voice and text services toward data driven alternatives such as Skype and Whatsapp manifest as a price increase.

Option B: Data Usage Approach

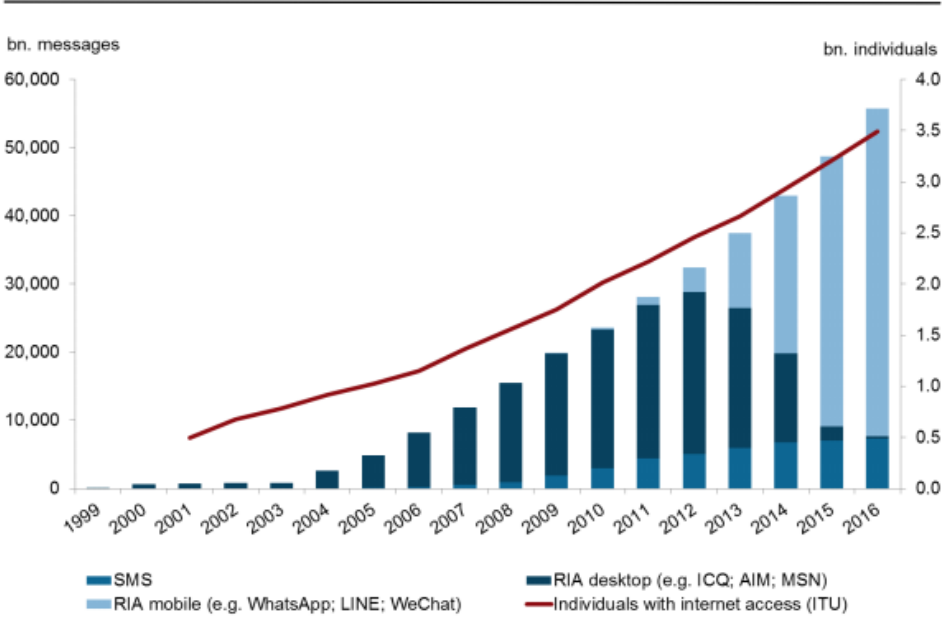
An alternative approach is to consider the supply side of the industry and evaluate what the output is. We have already discussed that most telecoms services can be viewed as

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

variants of the transmission of data. The primary service of the industry can therefore be seen as the transfer of data, as described above.

Converting the voice, texts and data services into a common volume measure (petabyte of data) shows that broadband and mobile data account for almost all data used from a volume perspective. It also shows that industry output, as measured by data transmitted, has increased over 900% between 2010 and 2015 which was 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 and towards more data driven applications. Figure E for example shows a rapid decline in the volume of SMS since 2012. According to Ofcom, the main reason for the decline is the increase in more sophisticated smartphone usage, which enable mobile users to access alternative communication methods such as email, instant messaging, including messaging services provided by handset makers and social networking sites.

Figure E: Substitution of SMS to Rich Internet Applications



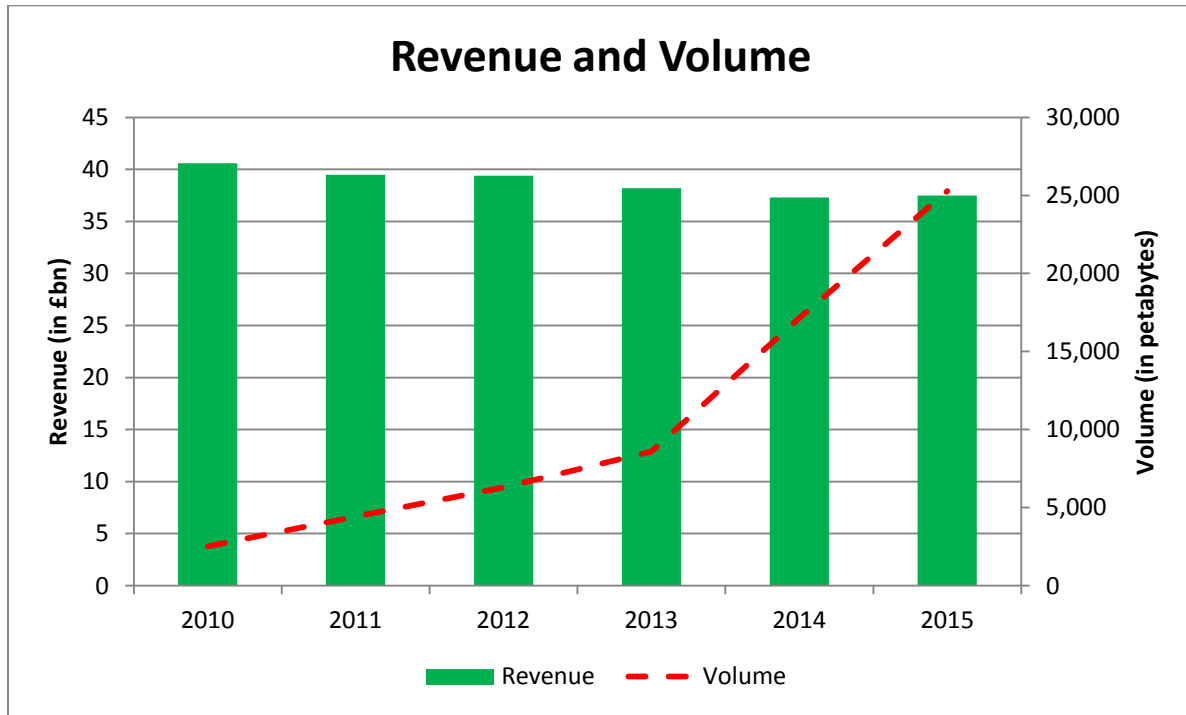
Source: WIK estimate based on Nielsen (cf. statisticbrain.com), press releases, International Telecommunications Union (ITU) and news articles.



By 2015, it is estimated that around 99.6% of the total volume was broadband and mobile data. This is in stark contrast to the revenue weights, where broadband and mobile data only account for around 40% of the total in 2015. Also, in contrast to the exponential increase in volumes, total revenue in the industry fell by around 8% between 2010 and 2015, see Figure F. This is mainly driven by a 40% decrease in

whole sale revenues. Retail revenues increased by around 4% in the same period (see Annex A for details).

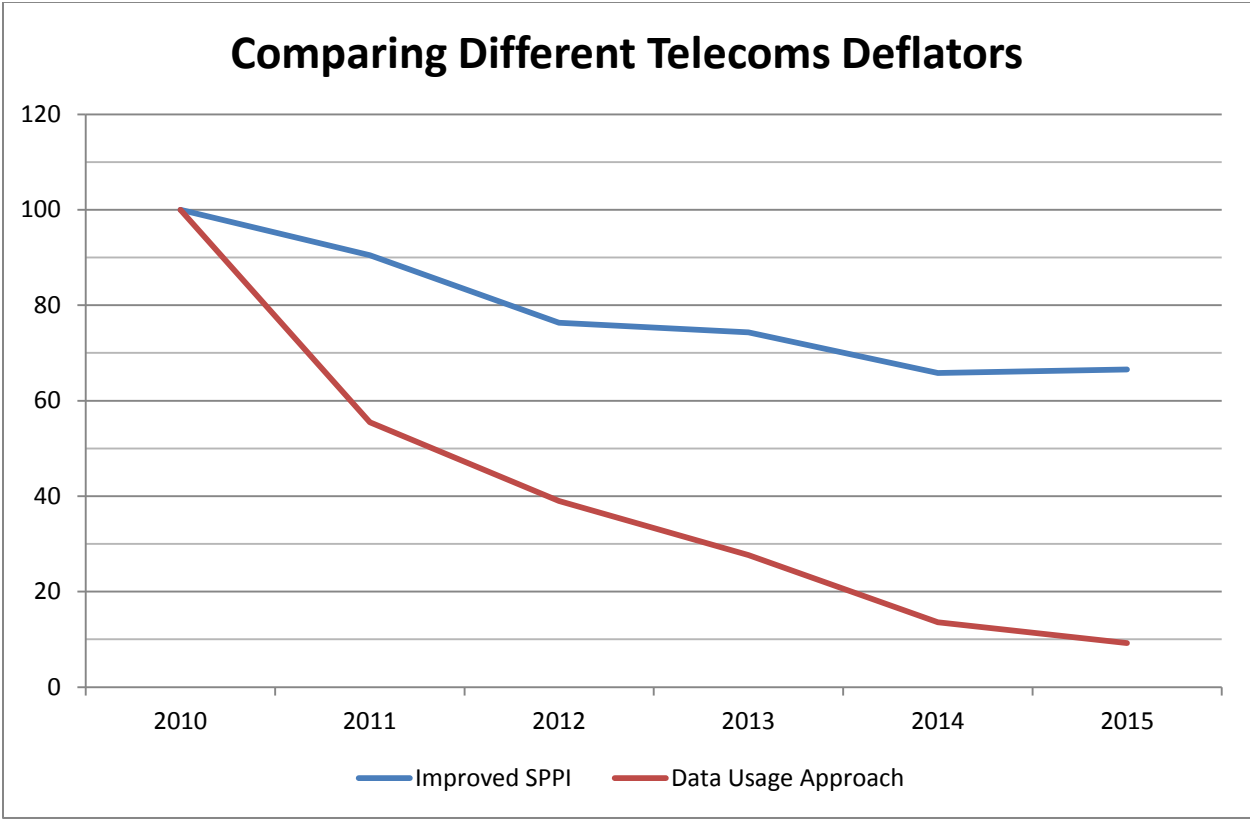
Figure F: Revenue and Volume in Telecommunications Services Industry



Option B is constructed using an aggregate unit value which divides total revenue²⁴ in the industry with the total data volume (see Annex B for technical details). This unit value represents the average price per bit transported. Between 2010 and 2015 this measure suggests that telecommunications services prices have decreased by around 90%, as shown in Figure G. An increase in data volume, with revenue broadly staying flat, is thereby seen as a volume increase and a price decrease. Likewise, a substitution away from pricier voice calls and texts messages towards cheaper services such as Skype and Whatsapp is also seen as a volume increase and a price decrease.

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

Figure G: Comparing Deflators



The strength of the data usage approach is that it better reflects the significant technical advances in the industry. That is because many of the technical and quality changes are manifested in an increased data volume, without further quality adjustments²⁵. Because some aspects of quality are inherent in the measure, an increased coverage, for example, would allow more people to get access to telecommunications services and thus increase data traffic. Likewise, an increase in speed would increase volume as users would be able to 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 paid for different communication services. The question is whether this is appropriate, given that consumers do appear to assign different values to the different services,

²⁵ The Bureau of Labour Statistics uses hedonic quality adjustment to adjust their PPI Internet Access Indices (see: <https://www.bls.gov/ppi/broadbandhedonicmodel.htm>). We discuss some of the problems of using price quotes and hedonic adjustment in the Context sections

given the difference in prices. On the other hand, a question remains whether the prices truly reflect consumer values in telecoms services. Our initial analysis indicates that phone calls cost many multiples of the equivalent data service. While there could be a stronger preference towards traditional call and text services, it is unlikely that the difference is of this magnitude.

RESULTS AND DISCUSSION

The results in figure G above show a substantial difference between the improved SPPI and the data usage approach. And while both deflators represent an improvement compared to the current methods, their incremental impact on real GDP growth would differ significantly in terms of magnitude. The key question is how to narrow this wide range and ultimately deliver a method which might be applied in National Accounts.

The two possible extensions are, firstly, to consider quality adjustment to the SPPI Index, around some of the characteristics of telecommunications which are not captured presently, such as coverage and latency. The second is to consider whether the data usage approach can be improved by considering the fixed infrastructure element in both the delivery and the pricing – the fixed line rental etc, which as shown in the SPPI index has been increasing in price in recent year; the index presented here attributes all the costs to the data transmitted. These improvements might help to bring these two approaches together, but we may need to start with a more basic question; which is why they give such starkly differing results in the first place?

Explaining the Price Difference in Telecommunications Services

The market for communication services is in a period of innovation, resulting in changes both in price and consumer behaviour (including significant growth in data usage), thanks to the remarkable engineering advances described above. 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 extreme 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 closing 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) who looked at the drugs market and found that generic drugs were also overweight in volume but underweight in revenue. However, they argued that some of the price differentials between generic and branded drugs (despite being near identical products) were explained by the brand value that consumers attached to the particular drugs. In the case of

telecommunications services, it is unclear whether brand value attribution is a possible explanation (although there is some evidence for brand value attribution in telecommunication equipment)²⁶. The issue is not the price difference for the same service such as phone calls that, say BT and Virgin Media (two major telecoms providers in the UK) charge. Instead, the main concern relates to the different prices that, say, BT charges for data, compared to other services, which have been converted into a data measure.

In practice, when there are brand new goods or improved quality 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 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 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 benefit from network effects that would not be captured in market prices. For one conceivable unobserved characteristic is the degree to which voice calls and text messaging applications act as platforms, such that the established platforms benefit from significant network effects. While special software or apps might be needed to make a phone call using the data line, the network internal 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 2016²⁸. However, to get to that stage, consumers have to know about the existence of cheaper

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>

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

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

and better platforms. We could therefore be experiencing a disequilibrium situation where consumers need time to learn about these alternative platforms.

Further, traditional platforms seem 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 which usually include an allowance of minutes, texts and data. Since consumers cannot opt out of the voice and text elements, they might continue to use traditional platforms. 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. using Skype or Whatsapp on the data line). 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 payment 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 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 downwardly biased estimate. This is particularly the case if consumers are substituting traditional voice and text services for data driven ones because they feel poorer and switch to a cheaper and 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 provide an indication if a message has been read and allow the users to set up status messages that help peers know whether someone is available to be contacted. Likewise, if consumers attach lower values to general data usage, for example streaming videos or browsing the internet, then these too should be lower weighted in the deflator. However, it is not clear if consumers do indeed attach lower values to data services. For example, data consumption, along with the usage of data driven alternatives to traditional phone calls and text messaging, has been

increasing substantially, despite the decrease in prices for traditional phone calls and text messages.

How much does the potential upward 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 example²⁹ where the price of each does not change between time periods, but the volume of calls via each method changes, and so total revenues change. We thereby contrast a Laspeyres/Paasche/Fisher type approach with one that views both traditional telephony and Skype (or any other data driven application) as comparable and calculates 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	1000	10	1	10	110	1010	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.

²⁹ These are not actual prices and volumes and are only used for illustrative purposes. It is worth pointing out that the above illustration uses a price relative of 10 but 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.

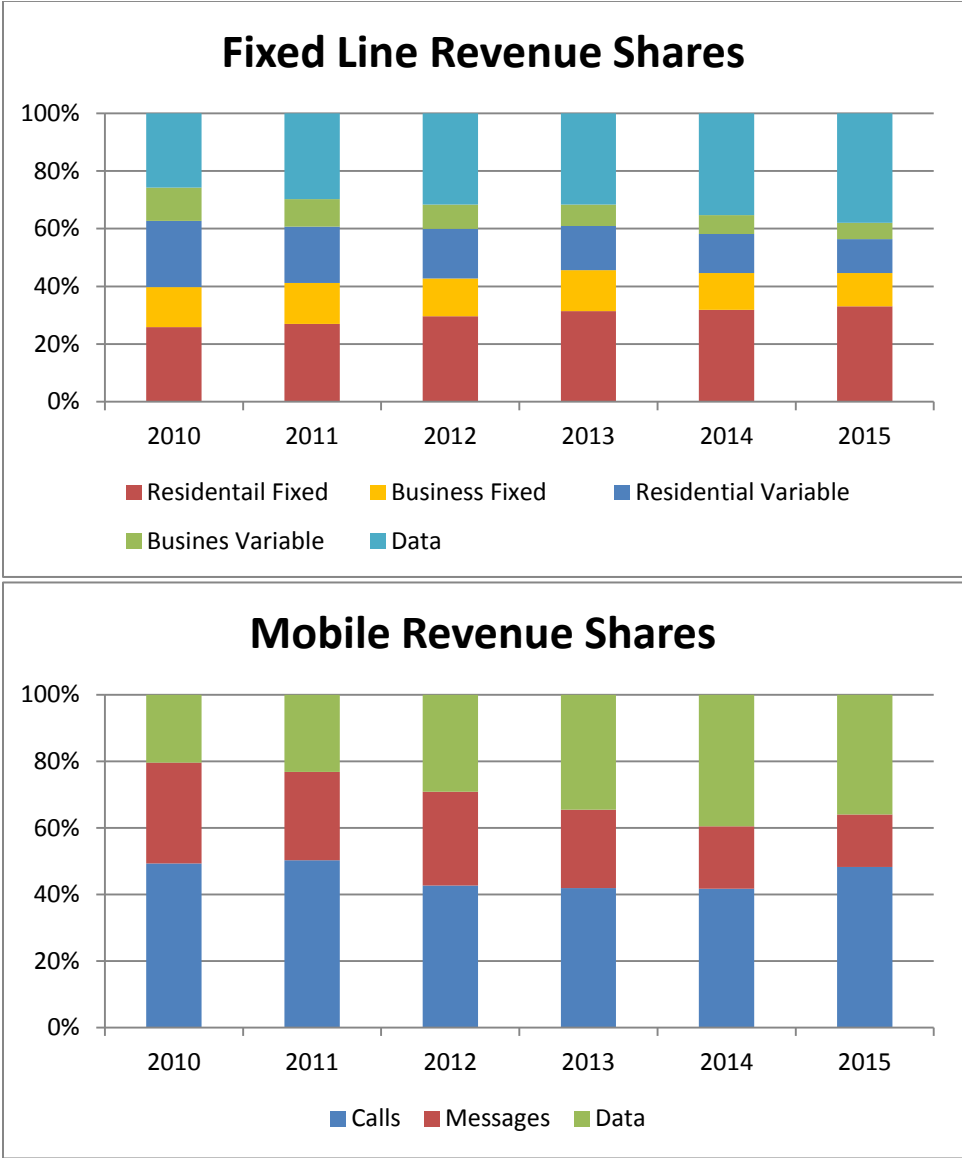
Despite all these caveats, it does not seem entirely unreasonable in this context to assume a high and rising degree of substitutability between different forms of communication services as users' behaviour adapts, rather than assuming none. In the context of telecommunications services, the question is then how homogenous the different services (voice, text, and data) are from another. Looking at the price differentials (described above) would suggest substantial differences, at least 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, often 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.

Convergence

Whilst the improved SPPI and the data usage approach appear substantially different at present, in future the movement in the deflators might converge. The share of overall revenue that was due to data usage increased between 2010 and 2015 for both fixed line and mobile telecommunications, see figure H. For example, we estimate that broadband data accounted for around 25% of total fixed line revenue in 2010, but by 2015, this had increased to almost 40%. Similarly, we estimate that mobile data accounted for around 20% of total mobile revenue in 2010, which had increased to around 35% by 2015. In both mobile and fixed line telecommunications, the share accounted for by voice calls and text messaging thereby 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 tend towards demonstrating a similar movement in prices.

Figure H: Fixed Line and Mobile Revenue Shares (weights for the indices)



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 identify how to chain link when existing products are converging to become a single, new product. However, if and until the movement in the two deflators converge, significant debate could remain regarding the ‘true’ value of the deflator and hence real GDP. In particular, the improved SPPI could be seen as a backward looking index, which is based on how users may have viewed

telecommunications services in the past. On the other hand, the 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 and reflects how users might view the services in future.

A specific obstacle to convergence at the moment is the existence of fixed line access charges, such as line rentals. As figure H shows, while the share of call charges for businesses and residential households decreased from around 35% in 2010 to 17% of total fixed line revenue in 2015, the share of residential and business access charges increased from around 40% to 45% 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.

Conclusions

The constant utility approach that informs price theory sits uncomfortably with the use of such price indices in practical applications to calculate real output and productivity from national accounts data. 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 production at all but is an aspect of economic welfare instead.

Our contribution in this paper has been to show that sensible improvements 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. As much discussed in previous research, this will be an upward biased deflator, and does not sufficiently take account of increasing consumer surplus 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, as it does not reflect either consumer

attributions of value for service characteristics or attributes such as market structure and price differentiation. However, 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 in the UK - and likely other countries - will have been understated in recent years.

Annex A: Breakdown of Revenue and Volume in Telecommunications Industry

Revenue Breakdown (in £bn)

	2010	2011	2012	2013	2014	2015
Wholesale services	10.1	8.9	8.3	7.5	6.5	6.2
Retail fixed	12.6	12.5	12.5	12.6	13	13.5
Retail mobile	15.1	15.4	15.9	15.5	15.2	15.2
Corporate data services	2.7	2.8	2.7	2.7	2.6	2.6
Total	40.6	39.5	39.4	38.2	37.3	37.5

Volume Breakdown (in Petabyte)

	2010	2011	2012	2013	2014	2015
Total Voice (PB)	122	116	112	109	105	104
Texts (PB)	0.018	0.021	0.021	0.018	0.015	0.014
Fixed Line Broadband (PB)	2,352	4,223	6,017	8,208	16,495	24,305
Mobile Data (PB)	53	94	165	283	533	873
Total (PB)	2,527	4,433	6,294	8,600	17,133	25,282

ANNEX B: Method guide to the Data Usage Approach

Data Sources

1. We use Ofcom's Communication Market Report 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. Mobile data volumes
3. For the most part, the data points are available for the period 2010-2015. 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 WhatasApp & 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

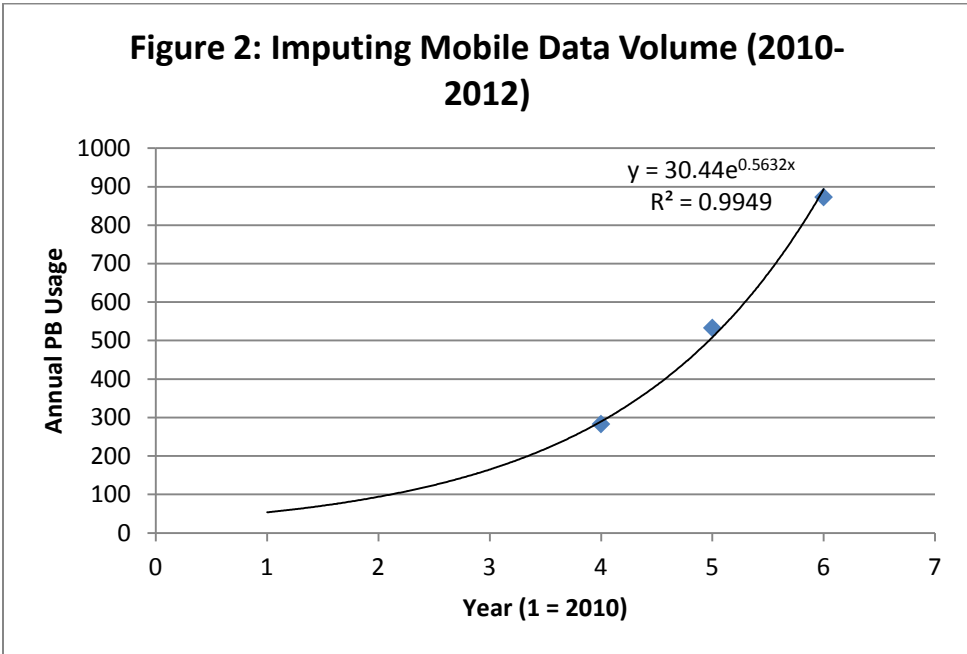
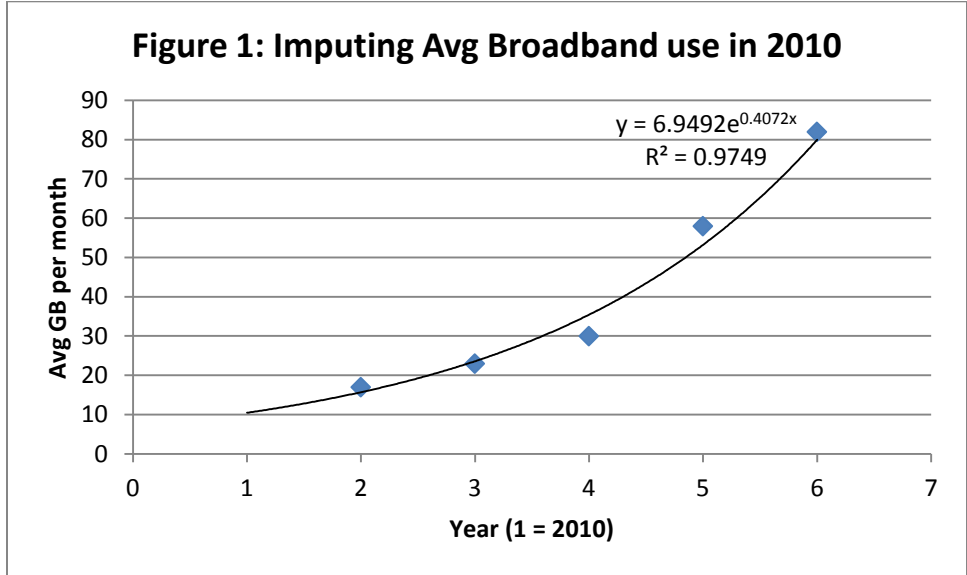
6. At present we do not distinguish between SMS and MMS. While we do not think that the volume of MMS would make a significant difference to our results, we will investigate this further.

Extrapolating missing values

7. The average fixed broadband use data is only available for the period 2011-2015 and the mobile data use data is only available for the period 2013-2015.
8. Since we are trying to construct a deflator for the period 2010-2015 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 1 and 2 below)

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



Imputing Total Fixed Broadband Usage

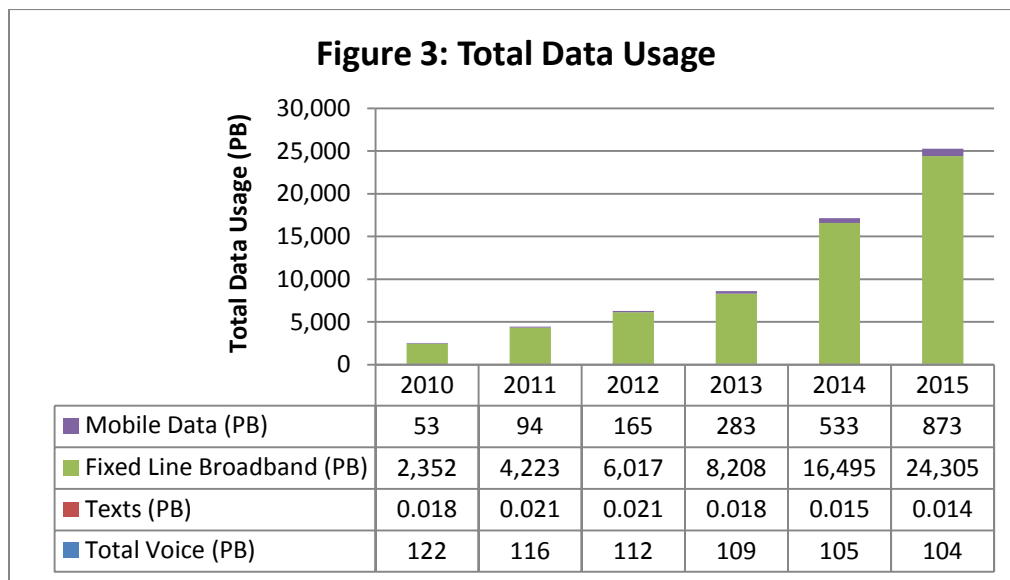
10. For fixed broadband usage, we only have the average fixed usage for a particular month in a year. We therefore have to make the simplifying assumption that the average for that particular month stays constant throughout the year

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.

Total Data usage

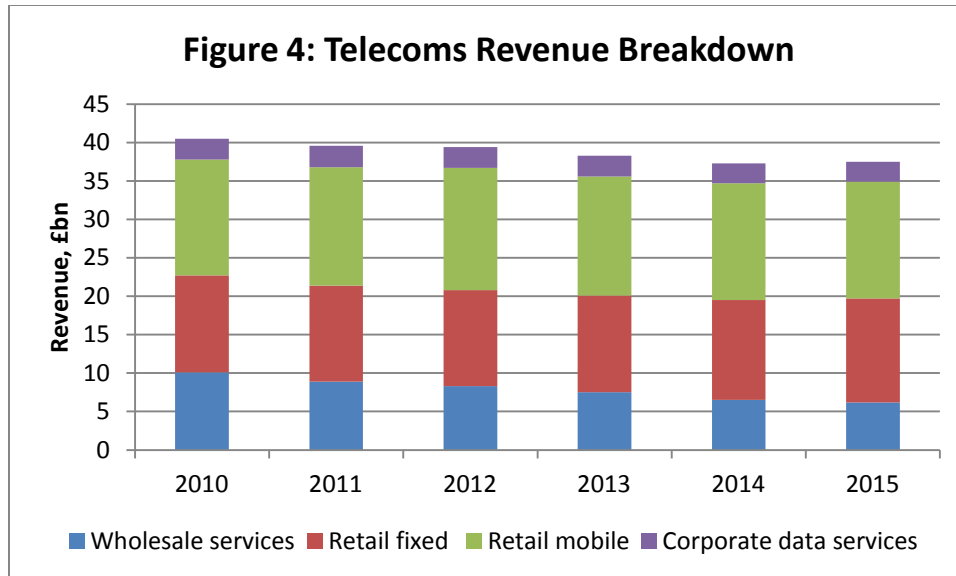
13. Figure 3 shows a breakdown of our estimated yearly data usage.
14. Almost all (or 99.6%) of the total data usage in 2015 is thereby estimated to come from fixed broadband (around 96%) and mobile data (around 3%).
15. Voice calls only contributed around 0.4% to the total data usage in 2015 (down from 4% in 2010), while text messages contributed only insignificantly to the total data volume since 2010.



Total Revenue Breakdown

16. Figure 4 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 bytes³⁰.

³⁰ 1 byte = 8 bits



17. 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:

- 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

18. 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.

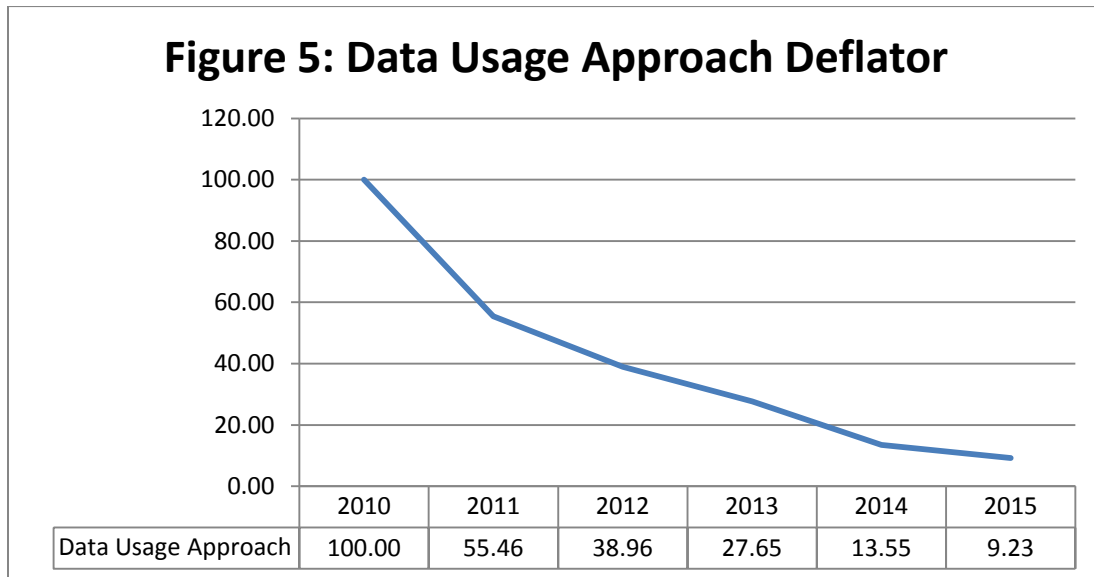
19. Table 1 below shows the average cost of data for different measurement units.

Our estimates thereby suggest that the cost of data transfer has declined by around 91% between 2010 and 2015.

Table1:	2010	2011	2012	2013	2014	2015
£/PB	£ 16,066,571	£ 8,910,097	£ 6,259,694	£ 4,442,070	£ 2,177,043	£ 1,483,270
£/TB	£16,067	£8,910	£6,260	£4,442	£2,177	£1,483
£/GB	£16.07	£8.91	£6.26	£4.44	£2.18	£1.48
£/MB	£0.016	£0.009	£0.006	£0.004	£0.002	£0.001

20. 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)

21. The resulting index can be seen in Figure 5 below.



ANNEX C: Method guide to the Improved SPPI

Data Sources

1. We obtain our data from Ofcom's Telecommunications Market Data Tables and Communications Market Report
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

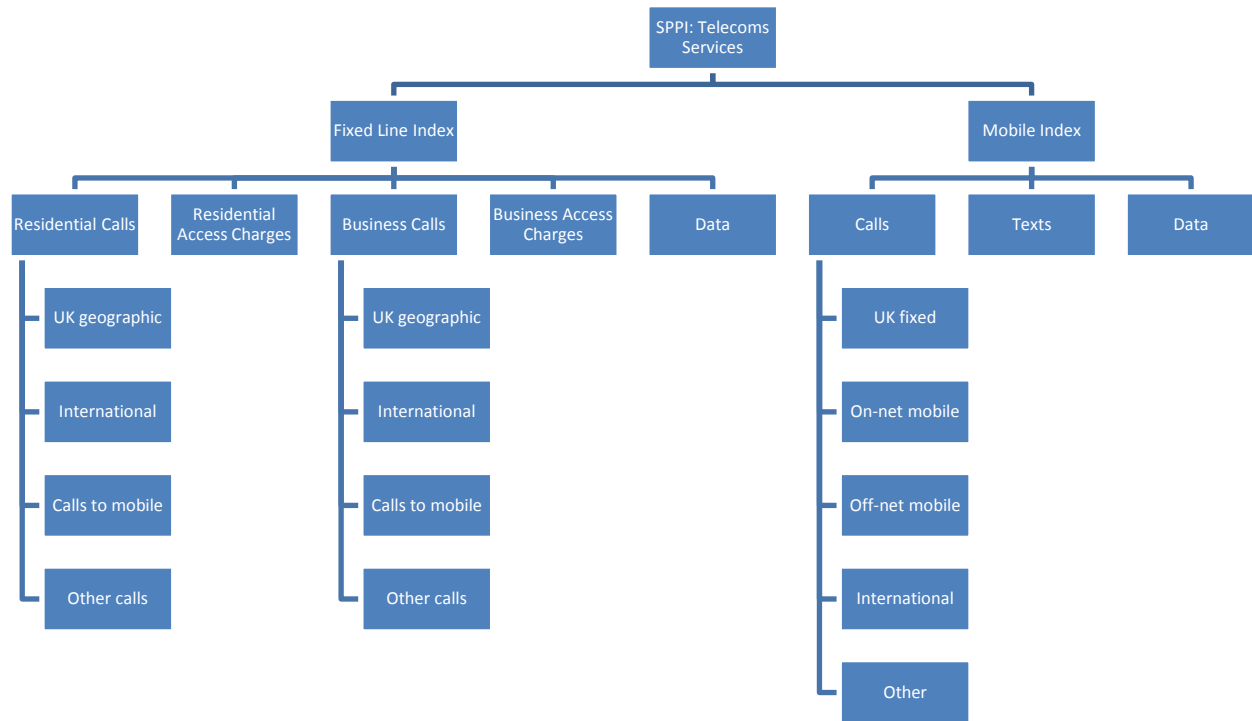
3. From the Communications Market Report we obtain the following series:
 - a. Summary of UK telecoms revenues
 - b. Average fixed broadband data use

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 1 shows the Aggregation Structure of the improved SPPI

Figure 1: 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

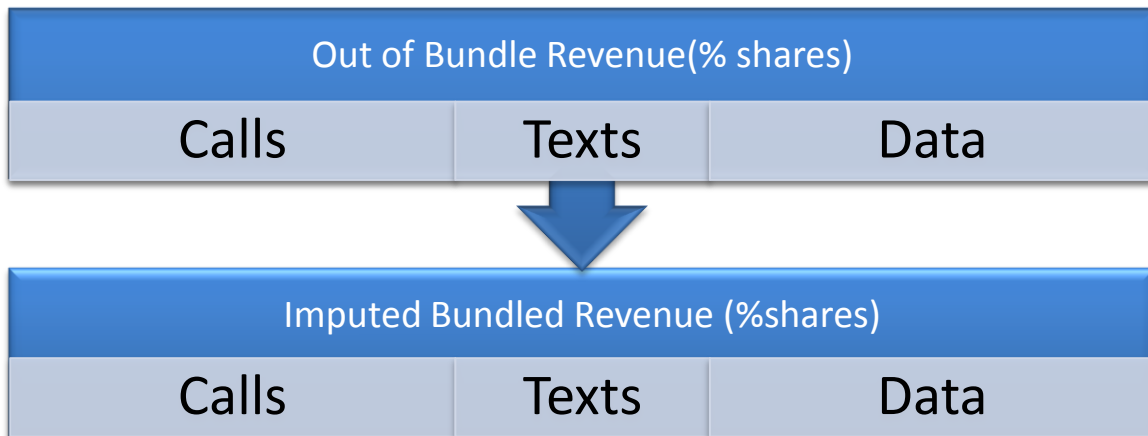
volume for 2010 following the same approach as in the data usage approach. See Annex B, paragraphs 7-12 for details.

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 total volumes for mobile data are only available for the years 2013-2015. We impute the missing values for 2010-2012 following the same approach as the data usage approach. See Annex B, paragraphs 7-9.
- 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 2.

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.

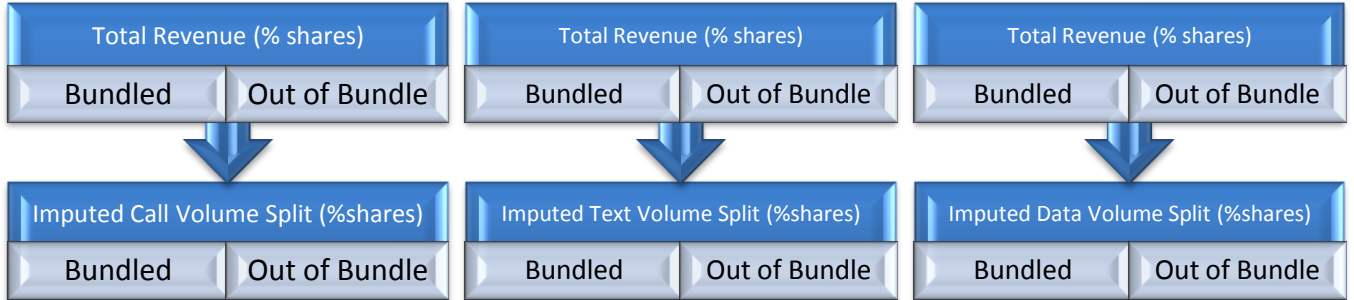
Figure 2: Imputing Breakdown for Bundled Revenue



- 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

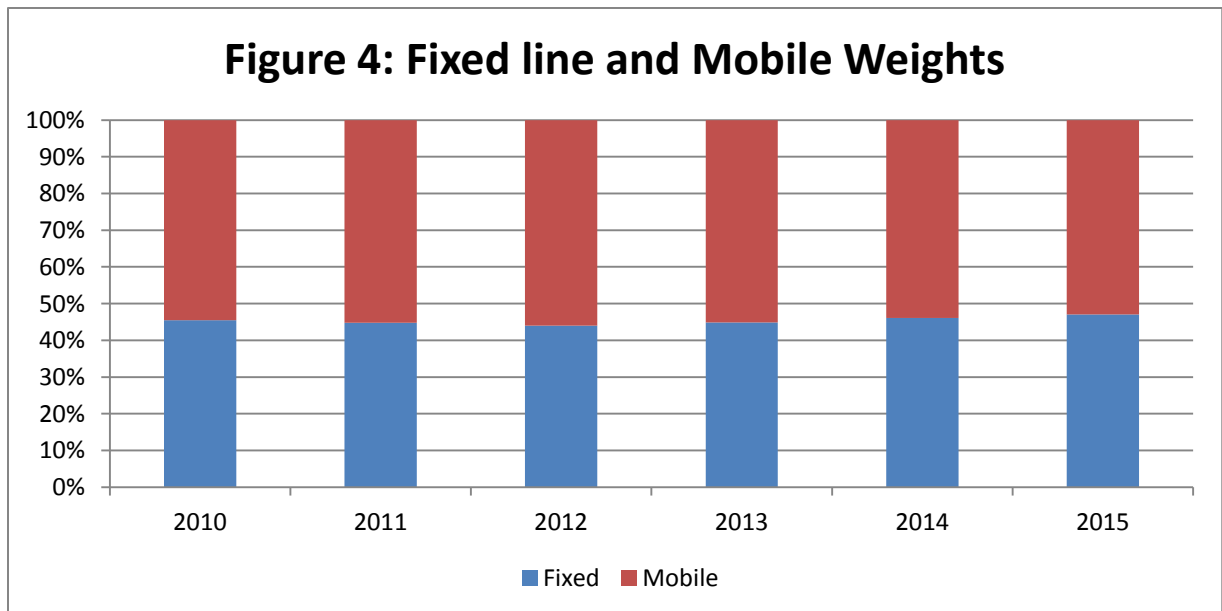
Figure 3: Imputing Volume Splits



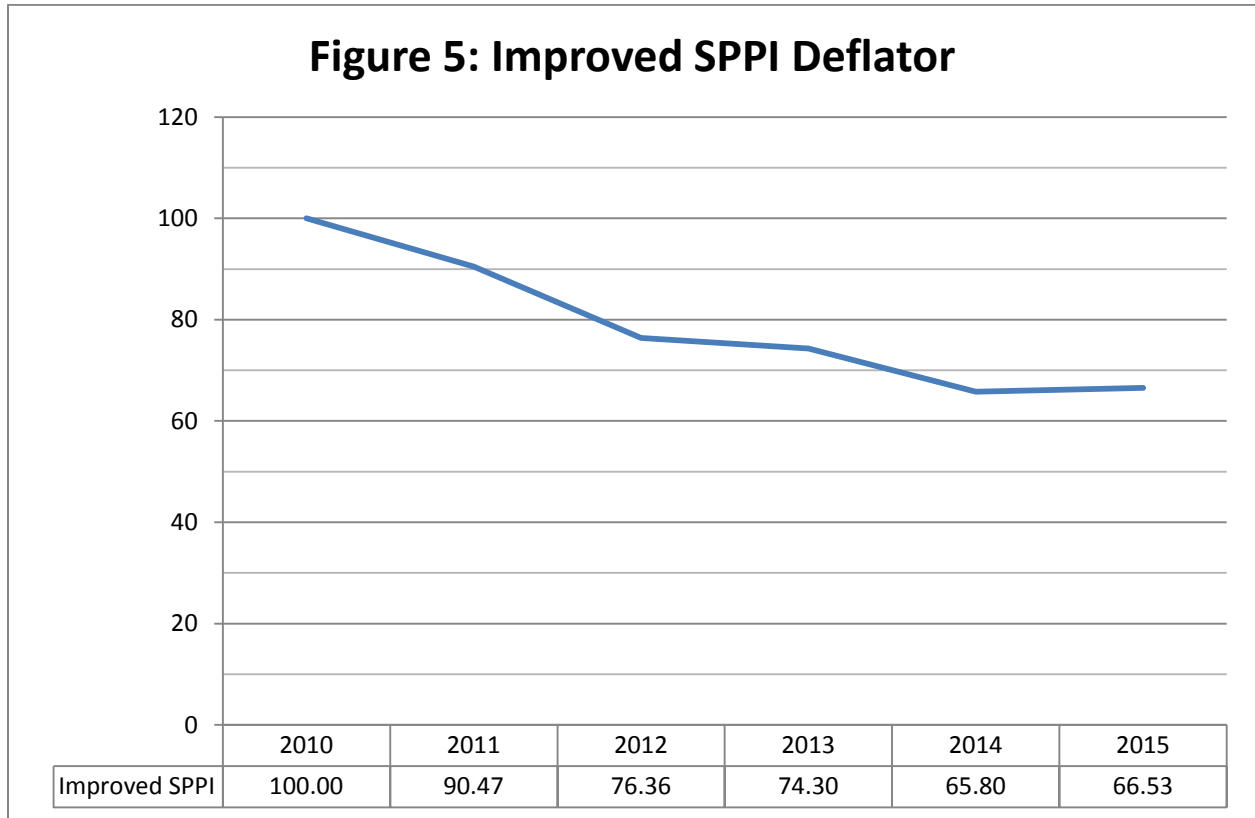
19. All unit values are then calculated on a bundled and out of bundled charge basis. These are then aggregated up to a Bundled and Out of Bundle Mobile Indices using revenue weights.
20. Finally we aggregate the Bundled and Out of Bundle Mobile Indices using revenue weights to get an overall Mobile Index as shown in Figure 1.

Overall Index

21. To get an overall index for the improved SPPI we aggregate the Fixed Line and Mobile Indices using revenue weights. Figure 4 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



22. Figure 5 shows the overall improved SPPI series.



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