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Online Appendix C1 – 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:

Assumption 2: 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 (Figures C1-I).
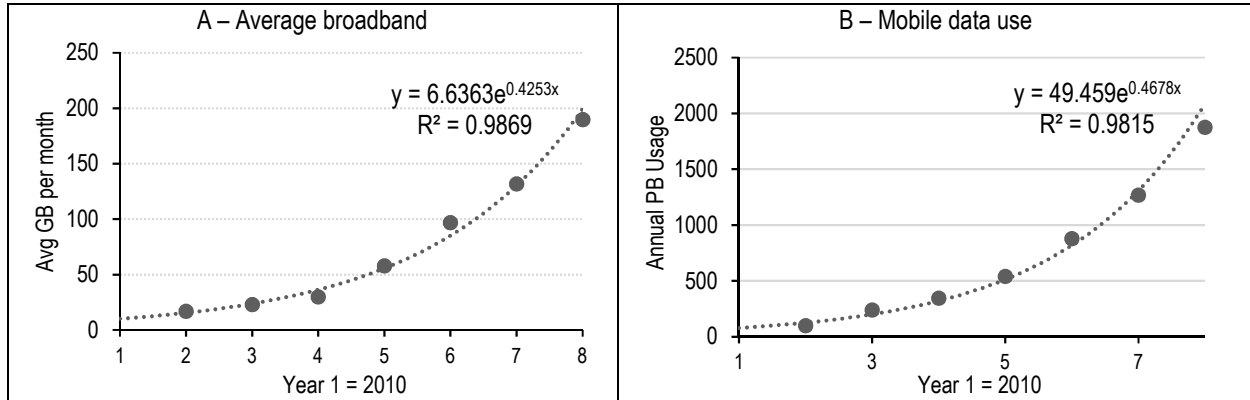
Assumption 3: Fixed and Mobile data use follows an exponential trend.

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Figure C1-I – **Imputing average broadband and mobile data use in 2010**

Sources: Authors' own calculations.

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).
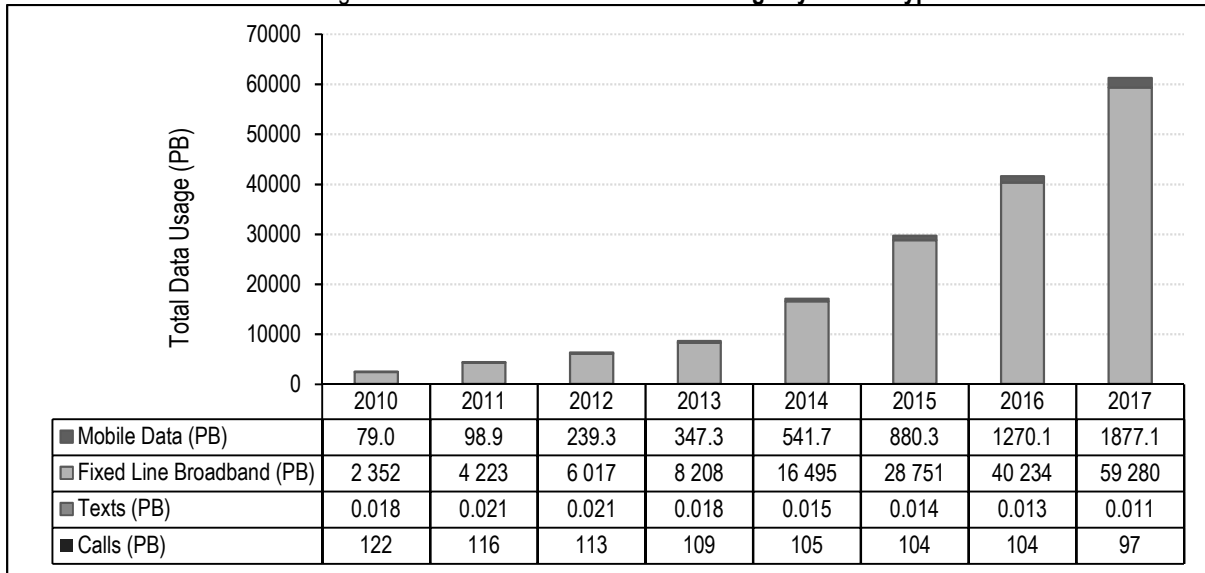
Total Data Usage

14. 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%) (Figure C1-II).
15. 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.

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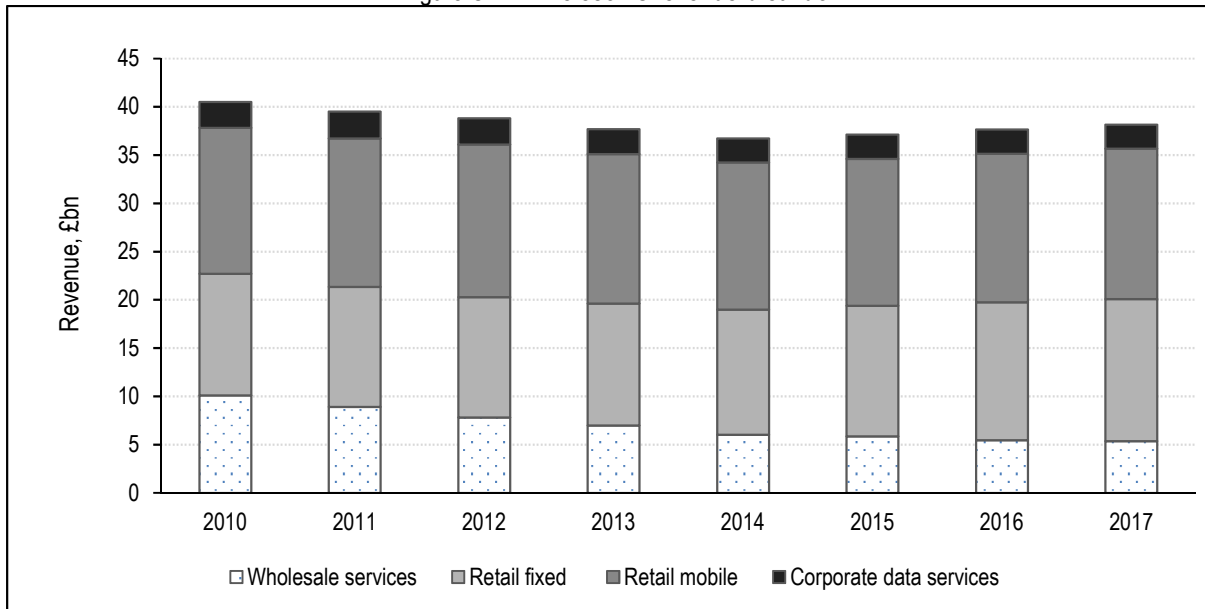Figure C1-II – **Breakdown of total data usage by service type**

	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

Sources: Authors' own calculations.

Total Revenue Breakdown

16. The revenue breakdown for the Telecommunications industry is shown below (Figure C1-III). 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.

Figure C1-III – **Telecoms revenue breakdown**

Sources: Ofcom, Authors' own calculations.

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17. The revenue for corporate data services is estimated for 2017.
18. 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).

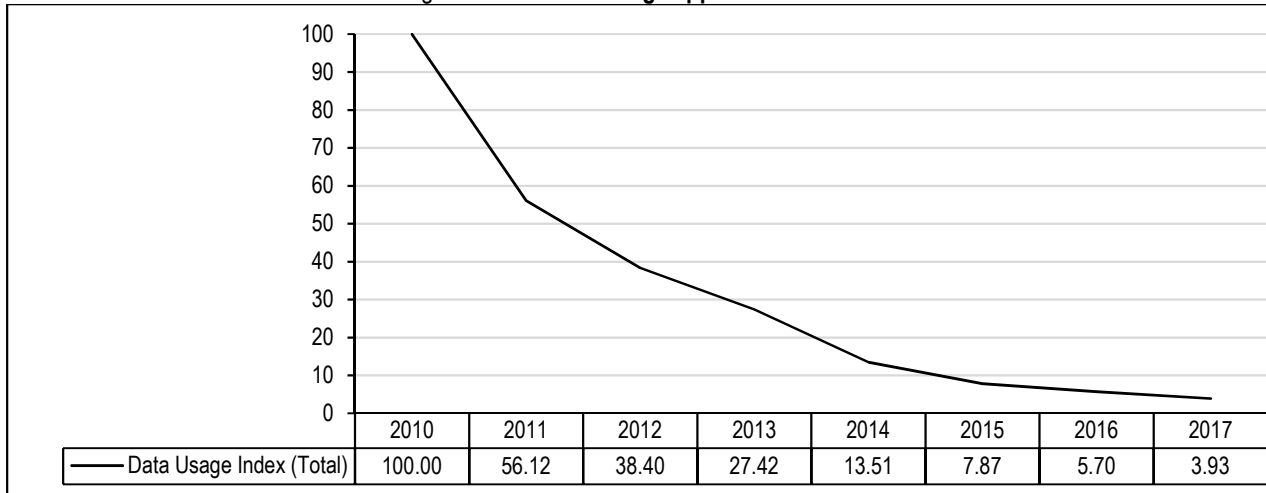*Average Price and Resulting Deflator Series*

19. 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.
20. Our estimates thereby suggest that the cost of data transfer has declined by around 96% between 2010 and 2017 (Table C1-1).

Table C1-1 – **Average cost of data transmission for different measurement units**

	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

21. Using the information in Table C1-1, 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).
22. The resulting index can be seen in Figure C1-IV below.

Figure C1-IV – **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

Sources: Authors' own calculations.

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Online Appendix C2 – 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:
   a. Fixed Line Telecommunication:
      i. Summary of residential exchange line numbers at end of quarter by operator;
      ii. Summary of business exchange line numbers at end of quarter by operator;
      iii. Summary of residential network access & call revenues by operator;
      iv. Summary of business network access & call revenues by operator;
      v. Summary of residential call volumes by call type and operator;
      vi. Summary of business call volumes by call type and operator;
      vii. Summary of residential call revenues by call type;
      viii. Summary of business call revenues by call type.
   b. Mobile Telecommunication:
      i. Call and message volumes by call type;
      ii. Estimated retail revenues generated by mobile telephony.
3. From the Communications Market Report we obtain the following series:
      i. Summary of UK telecoms revenues;
      ii. Average fixed broadband data use;
      iii. Average mobile data usage;
      iv. 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 C2-I shows the aggregation structure of the 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 straightforward.
9. 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.
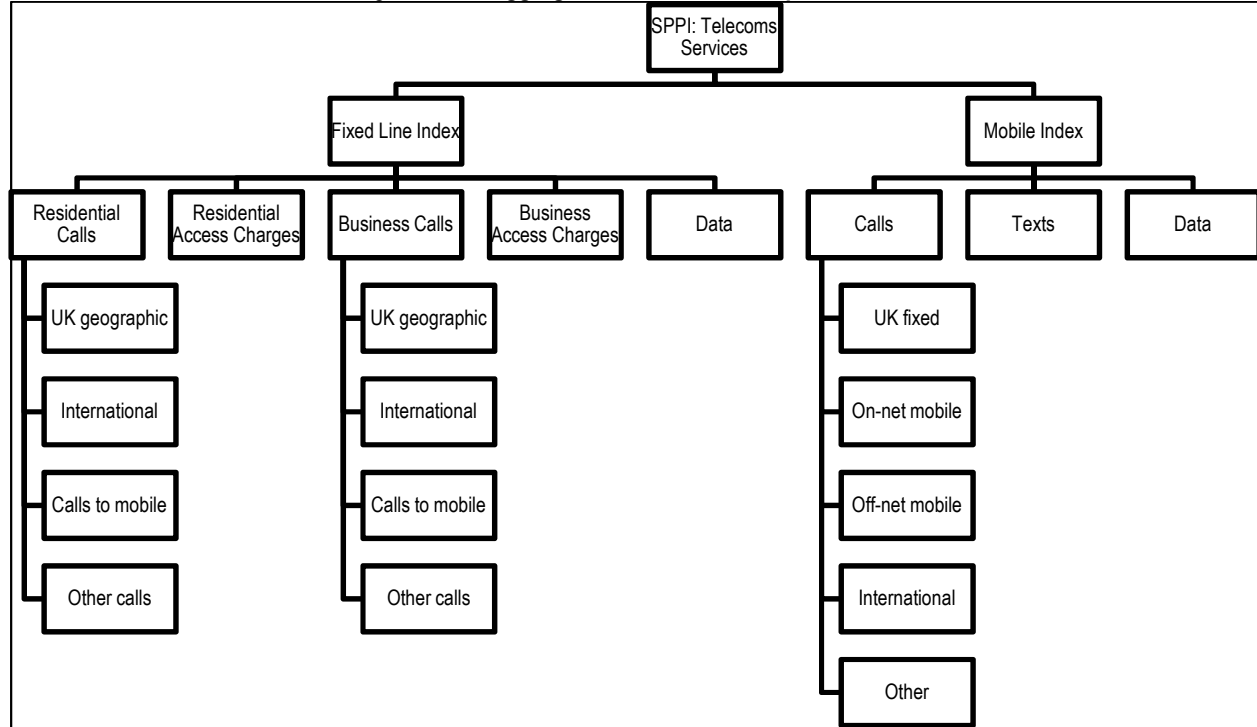
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10. The Fixed Line Index also includes charges for data services. The construction of the unit values for data services follows the same approach as the data usage approach. While we have data services revenue for all years, we are missing the data volume for 2010. We extrapolate the data volume for 2010 following the same approach as in the data usage approach. See Annex A, paragraphs 7-13 for details.

Figure C2-I – **Aggregation structure for improved SPPI**

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 A, 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-II.

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.

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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.

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 C2-III.
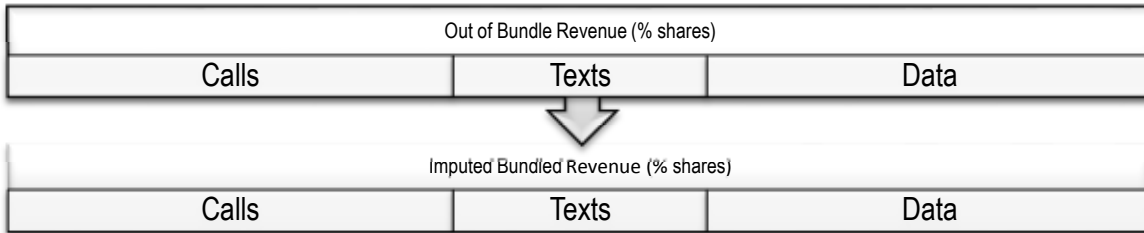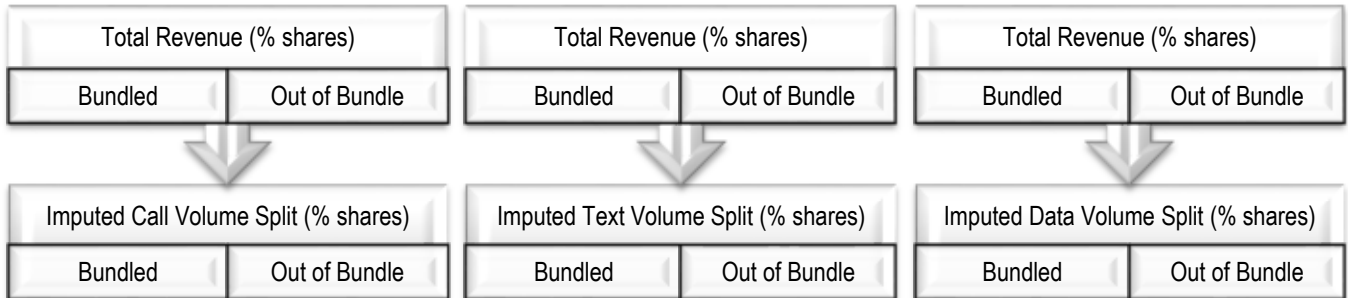
Figure C2-II – **Imputing breakdown for bundled revenue**

Out of Bundle Revenue (% shares)		
Calls	Texts	Data

Imputed Bundled Revenue (% shares)		
Calls	Texts	Data

Figure C2-III – **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

Overall Index

21. To get an overall index for the improved SPPI we aggregate the Fixed Line and Mobile Indices using revenue weights. Figure C2-IV 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.
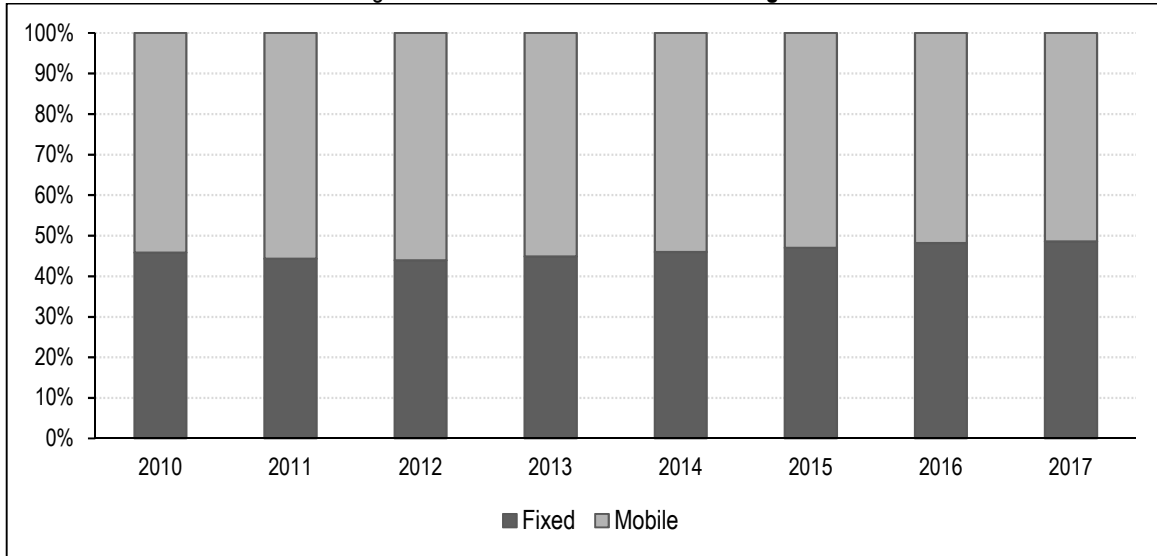22. Figure C2-V shows the overall improved SPPI series

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Figure C2-IV – **Fixed line and mobile weights**

Fixed   Mobile

Sources: Authors' own calculations.

Figure C2-V – **Improved SPPI Deflator**

	2010	2011	2012	2013	2014	2015	2016	2017
Série1	100.00	94.82	76.55	75.85	67.53	66.68	64.54	63.32