



Zero-Rating in the EU

**An empirical investigation into the effects on
data caps and prices in 15 countries**

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Executive Summary (Deutsch)

Zero-Rating wird in der Europäischen Union (EU) von mehreren Mobilfunkbetreibern praktiziert. Dabei wird der Datenverbrauch bei der Nutzung bestimmter Applikationen (Apps) oder Dienste nicht vom im Tarif inkludierten Datenvolumen abgezogen. Zero-Rating kann dabei in verschiedene Formen auftreten: In manchen Fällen gilt es nur für eine bestimmte App, in anderen Fällen für eine Kategorie von Apps (bspw. Zero-Rating für soziale Medien oder für Musik), und kann entweder im Tarif inkludiert oder als Zusatzpaket erhältlich sein.

Die Diskussion über Zero-Rating ist Teil einer breiteren europäischen Debatte zum Thema Netzneutralität. Netzneutralität wird in der EU durch die Verordnung (EU) 2015/2120 geregelt („Netzneutralitätsverordnung“). Diese Verordnung trat im April 2016 in Kraft und untersagt die technische Diskriminierung von Datenverkehr aufgrund des Inhalts sowie aufgrund des verwendeten Dienstes oder der verwendeten Applikation. Diese Verordnung hat zur Folge, dass Zero-Rating nicht auf bestimmte Apps oder Dienste angewendet werden darf, sobald der Endkunde sein im Tarif inkludiertes Datenvolumen erreicht bzw. überschritten hat. Jedoch ist Zero-Rating nicht explizit verboten, solange das inkludierte Volumen nicht erreicht wurde, da es in diesem Fall als unterschiedliche Behandlung aufgrund „kommerzieller“ und nicht technischer Merkmale gilt.

Befürworter des Zero-Ratings sind der Ansicht, dass es mobiles Breitband attraktiver für Kunden mache und ihnen die Gelegenheit gäbe, mehr (Datenvolumen) für bestimmte Apps und Dienste zu konsumieren. Als Wettbewerbsparameter am Endkundenmarkt erlaube es Betreibern, ihre Produkte von jenen anderer Wettbewerber zu differenzieren. Gegner hingegen vertreten die Ansicht, dass Zero-Rating die Wahlfreiheit von Konsumenten einschränke, da es ihnen Anreize zur Nutzung jener Apps gäbe, die der Anwendung von Zero-Rating unterliegen. Langfristig könne es sogar Eintrittsbarrieren für neue Applikationen errichten und somit die Auswahl für Nutzer weiter einschränken.

Bisher wurden zwar mehrere theoretische Studien zu Zero-Rating publiziert, jedoch kaum empirische Untersuchungen. Diese Studie soll dazu beitragen, diese Lücke zu schließen. Dafür werden Tarifdaten (die auch Informationen über Zero-Rating enthalten) von über 11,000 Tarifen von 53 Mobilfunknetzbetreibern in 15 EU Mitgliedsstaaten in Zeitrahmen von 2015-2018 analysiert, mit dem Ziel, den Effekt von Zero-Rating auf das inkludierte Datenvolumen, Preise und Preise pro inkludierter Dateneinheit zu ermitteln.

Unseren Daten zufolge hat die Bedeutung von Zero-Rating insbesondere im Zeitraum H1/2015 bis H1/2018 (H1 bezeichnet das 1. Halbjahr) in den 15 betrachteten Ländern zugenommen: Die Anzahl der Mobilfunknetzbetreiber, die Tarife mit inkludiertem Zero-Rating anbieten, ist von nur fünf auf zwanzig gestiegen und der Anteil der Tarife in unserer Stichprobe, die Zero-Rating enthalten, von etwa 5% auf etwa 25%. Dieser Anteil variiert erheblich zwischen den Ländern und in den meisten Ländern auch im

Zeitverlauf. In der zweiten Jahreshälfte 2018 ist ein gewisser Rückgang des Anteils der Zero-Rating-Angebote zu verzeichnen, und einige Betreiber haben solche Angebote sogar gänzlich vom Markt genommen.

Während der Anteil der Angebote inklusive Zero-Rating zunahm, stiegen gleichzeitig auch die durchschnittlichen Data-Caps deutlich und in einigen Ländern auch der Anteil der Flatrate-Tarife. Ein Vergleich zwischen Tarifen mit Zero-Rating und Tarifen ohne Zero-Rating zeigt, dass Tarife mit Zero-Rating im Durchschnitt teurer sind, ein höheres Datenvolumen enthalten und einen niedrigeren Preis pro GB aufweisen.

Um die Unterschiede zwischen Tarifen mit und ohne Zero-Rating genauer zu analysieren, verwenden wir Regressionsanalysen, mit denen z.B. für andere Tarifmerkmale und systematische Unterschiede zwischen Betreibern und im Zeitverlauf kontrolliert werden kann. Darüber hinaus wenden wir auf Betreiberebene einen Basket-Ansatz an, der es uns ermöglicht festzustellen, wie sich Änderungen bei Zero-Rating auf andere Tarifmerkmale auswirken.

Zur „Messung“ von Zero-Rating verwenden wir drei verschiedene Variablen: Zwei auf Ebene der Tarife, wobei eine anzeigt, ob bei einem Tarif Zero-Rating inkludiert ist und die andere, ob Zero-Rating inkludiert ist oder als Option zur Verfügung steht. Bei unserem dritten Ansatz werden alle Tarife eines Betreibers markiert, wenn dieser Betreiber in der betreffenden Periode zumindest einen Tarif anbietet, bei dem Zero-Rating inkludiert ist („Portfolio-Ansatz“).

Über alle Länder und den gesamten Zeitraum hinweg finden wir keinen konsistenten Nachweis dafür, dass Zero-Rating das inkludierte Datenvolumen verringert oder die Preise pro GB oder die monatlichen Preise erhöht. Einige unserer Ergebnisse deuten eher darauf hin, dass Zero-Rating (ceteris paribus) mit höheren Datenobergrenzen und niedrigeren Preisen pro GB verbunden ist. Diese Ergebnisse sind jedoch nicht in allen unseren Spezifikationen statistisch signifikant.

Wenn wir den Effekt von Zero-Rating auf Länder- und Periodenebene betrachten, wird ersichtlich, dass die Richtung und Größe des Effekts (sowie seine statistische Signifikanz) von Land zu Land, aber auch innerhalb einiger Länder im Laufe der Zeit erheblich variieren. Wir können jedoch kein bestimmtes Muster identifizieren (z. B. eine Tendenz im Zeitverlauf oder auf Länderebene die Anzahl der Mobilfunknetzbetreiber oder Länder mit hoher Datenobergrenze im Vergleich zu Ländern mit niedriger Datenobergrenze), das zur Erklärung oder Vorhersage des Effekts beitragen könnte.

Schließlich betrachten wir den Effekt von Zero-Rating unterteilt nach verschiedenen Kategorien von Apps. Dabei zeigt sich, dass Tarife, in denen nur Social Media- und Chat-Apps enthalten sind, im Vergleich zur Kontrollgruppe (Tarife ohne Zero-Rating) mit einer höheren Menge an enthaltenen Daten und einem niedrigeren Preis pro GB einhergehen. Bei Tarifen, die nur zero-geratete Video- oder Audio-Apps enthalten, ist es dagegen tendenziell umgekehrt.

Insgesamt können wir den Schluss ziehen, dass es keinen systematischen Effekt von Zero-Rating auf andere Tarifmerkmale wie inkludierte Daten, den Preis oder den Preis pro GB zu geben scheint. Vielmehr scheint der Effekt über Länder, den betrachteten Zeitraum und zwischen Anwendungskategorien zu variieren. Unsere Ergebnisse unterstützen daher den regulatorischen Ansatz einer einzelfallbezogenen Bewertung der (potenziellen) Auswirkungen von Zero-Rating.

Executive Summary (English)

Zero-rating is a practice used by several mobile telephony operators in the European Union (EU). With zero-rating, the data traffic for certain services or applications (apps) does not count towards a tariff's data cap. Zero-rating may apply to a single application, a category of applications or several categories of applications such as social media, chat apps, and music or video apps, and may be included in a tariff or be available as an optional add-on.

Zero-Rating has to be viewed in the wider context of the net neutrality debate. Within the EU, the rules governing net neutrality are laid down in regulation (EU) 2015/2120, also called the "open internet regulation". This regulation, which entered into force in April 2016, prohibits technical discrimination of traffic based on its content, application, or service. Therefore, zero-rating of certain applications, once the "general purpose" data allowance has been used up, is not allowed, since this would amount to different technical treatment of traffic based on the application. However, as long as a customer is still within her or his data cap, zero-rating is not explicitly prohibited since it is "only" a commercially different treatment of data traffic, but not a technically different treatment.

Proponents of zero-rating claim that it makes mobile broadband more attractive to end users and gives them the opportunity to consume more (data) for certain applications. It is an element of retail competition allowing operators to differentiate their products. Opponents on the other hand argue that zero-rating restricts the choice of end users since it incentivises them to use certain apps, namely the ones which are zero-rated. It may even increase barriers to entry for new apps, further decreasing users' choice in the long run.

As of today, there are several theoretical studies on zero-rating, however, there is hardly any empirical evidence on the matter. This study contributes to fill this gap. It uses tariff-level information (including information on zero-rating) for more than 11,000 tariffs of 53 mobile network operators (MNOs) in 15 EU countries over the period 2015-2018 in order to investigate the effects of zero-rating on data caps, prices and prices per unit of included data.

According to our data, the importance of zero-rating increased in particular in the period H1/2015-H1/2018 (H1 indicates the 1st half of the year): The number of MNOs offering tariffs which include zero-rating of certain applications grew from just five to twenty and the share of tariffs in our sample which include zero-rating from about 5% to about 25%. This share varies significantly across countries and in most countries also across time. In the second half of 2018, we see a certain decline in the share of zero-rating offers and some operators even stopped offering such features at all.

While the share of offers including zero-rating increased, also average data caps increased significantly and in several countries also the share of flat rate tariffs. A comparison between tariffs that include zero-rating and tariffs that do not include

zero-rating shows that tariffs including zero-rating are on average more expensive, have higher data volumes included, and a lower price per GB.

To analyse the differences between tariffs with and without zero-rating included in more detail, we use regression techniques to control e.g. for other tariff characteristics and systematic differences between operators and over time (operator and time fixed effects). In addition, we also apply a basket approach on the operator level, which allows us to track operators over time to see how changes in the share of offers including zero-rating of a certain operator effect other tariff characteristics.

We apply three different measures for zero-Rating: Two are on the tariff level, one measuring if zero-rating is included in a certain tariff, and one measuring if zero-rating is included or available as an optional add-on. The third approach identifies all tariffs of an operator if this operator offers at least one tariff with zero-rating included at a certain point in time ('portfolio approach').

Considering the effects across all countries and periods, we do not find consistent evidence that zero-rating decreases included data volumes or increases prices per GB or monthly prices. Some of our results rather suggest that zero-rating is ceteris paribus associated with higher data caps and lower prices per GB. These results are, however, not robust across all of our specifications.

If we consider the effect of zero-rating on a country- and period level, we find that the direction and size of the effect (as well as its statistical significance) varies significantly across countries, but also within some countries over time. We cannot identify a particular pattern, however (e.g. a tendency over time or on a country level the number of MNOs or high data cap vs. low data cap countries), which could help to explain or predict the effect.

Finally, we consider the effects of zero-rating split by different categories of apps. We find that tariffs that only include social media and chat apps usually seem to be associated with a higher amount of included data and a lower price per GB compared to tariffs without zero-rating included. For tariffs in which only zero-rated video or audio apps are included, on the other hand, it is more the other way around.

Overall, we can conclude that there does not seem to be a systematic effect of zero-rating on other tariff characteristics such as included data, price and price per GB. Rather, the effect seems to vary across countries, periods and categories of applications. Our results are therefore supportive for a case-by-case approach to the assessment of the (potential) effects of zero-rating.

1 Introduction

Zero-rating is a practice used by several mobile telephony operators in the European Union (EU). With zero-rating, the data traffic for certain services or applications does not count towards a tariff's data cap. Zero-rating may come in different forms, e.g.

- for a single application, a category of applications or several categories of applications such as social media, chat apps, and music or video apps;
- Zero-rating may only apply as long as a user has not used up its "general purpose" data volume (volume not tied to a specific application or group of applications) or even beyond;
- Zero-rating may be included in a tariff or be available as add-on;
- The data volume for zero-rating services can be unlimited or capped (in the latter case it is sometimes referred to as "application specific data");
- If a content and application provider pays the mobile operator to provide additional data volume for its application, this is referred to as sponsored data.

Zero-Rating has to be viewed in the wider context of the net neutrality debate. Net Neutrality means that all data traffic transmitted over the internet is treated without discrimination or interference based on the origin or destination of the traffic or its content, application, or service.

Within the EU, the rules governing net neutrality are laid down in regulation (EU) 2015/2120, also called the "open internet regulation".¹ This regulation, which entered into force in April 2016, prohibits technical discrimination of traffic based on its content, application, or service. Therefore, zero-rating of certain applications once the "general purpose" data cap has been used up is not allowed, since this would amount to different technical treatment of traffic based on the application. However, as long as a customer is still within her or his data cap, zero-rating is not explicitly prohibited since it is "only" a commercially different treatment of data traffic, but not a technically different treatment.

Proponents of zero-rating claim that it would make mobile broadband more attractive to end users and would give them the opportunity to consume more (data) for certain applications. It is an element of retail competition allowing operators to differentiate their products. Opponents on the other hand argue that zero-rating restricts the choice of end users since it incentivises them to use certain apps (those which are zero-rated). It may even increase barriers to entry for new apps further decreasing users' choice in the long run.²

¹ Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015 laying down measures concerning open internet access and amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services and Regulation (EU) No 531/2012 on roaming on public mobile communications networks within the Union, Official Journal L 310/1 from 26.11.2015 (see <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2120&from=EN>).

² See also the "BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules", which discuss under which circumstances zero-rating could materially reduce end-users' choice

As of today, there are several theoretical studies on zero-rating, however, there is hardly any empirical evidence on the matter. This study contributes to fill this gap. It uses tariff-level information (including information on zero-rating) for more than 50 mobile network operators (MNOs) in 15 EU countries over the period 2015-2018 in order to investigate the effects of zero-rating on data caps, prices, and prices per unit of included data.

The study is structured as follows: In section 2, possible effects of zero-rating are discussed based on the related literature. Section 3 describes the dataset and shows developments of zero-rating offers for the 15 EU countries as well as the development of important tariff characteristics such as included data (the size of the data caps), the share of flat rate offers and prices (including prices per GB) in the period 2015-2018. In section 4 we first describe our empirical approach to identifying the effects of zero-rating on data caps, prices and price per Gigabyte (GB), then we present the estimation results. Section 5 concludes.

2 Possible Effects of Zero-Rating on data caps and prices

There is already a significant amount of literature dealing with the effects of zero-rating. Most studies are theoretical (economic models), however, or have a survey character. We only found two studies applying econometrics to measure the effects of zero-rating, but both have significant data limitations.

First, we briefly discuss the theoretical studies. Most of them look at the incentive an internet service provider (ISP) has to introduce zero-rating and which effects on welfare and competition such offers may have. Some papers also look at the consequences of regulatory intervention banning or restricting zero-rating practices.

Krämer and Peitz (2018), for example, is a recent summary of such literature. They conclude that the welfare effects of zero-rating strongly depend on the market environment and therefore an assessment should be made on a case-by-case basis.³ The study mentions the following motivations for ISPs to introduce zero-rating:

- To gain revenues from content and applications providers (CAPs);
- To increase revenues from consumers by means of price discrimination and tailoring;
- Improving the market position by product differentiation;
- Traffic management (if operators apply zero-rating together with throttling).

In the EU context we consider the second and the third motivation as most likely since, to our knowledge, revenues from CAPs are the exception rather than the rule and throttling of certain applications is prohibited under the current EU regulations.

https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/6160-berec-guidelines-on-the-implementation-b-0.pdf, p. 11-13).

³ See also the literature review in Howell and Layton (2016) which reaches a similar conclusion.

The theoretical literature investigates different possible effects of zero-rating, e.g. on the exclusion of content providers (Gautier and Somogyi, 2018) or capacity investments (Hoernig and Monteiro, 2018 and Lorenzon and da Cruz, 2019).

As we examine the influence of zero-rating on included data and prices (monthly fee, price per GB), hypotheses in the literature with regard to these aspects are of particular interest.

EC (2017), a report on zero-rating practices prepared for the European Commission in 2017, quotes several claims, which have been made on the issue of data caps (see pp. 119-120). E.g. net neutrality advocates would be of the opinion that ISPs may have incentives to impose tighter data caps when introducing zero-rating. One motivation may be to introduce or raise charges to CAPs, another to push their own services or simply to make their zero-rating offer more attractive. EC (2017) quotes some anecdotal evidence mainly provided by the Finish consultant Rewheel in this context.

EC (2017) views such claims as “somewhat speculative”, however. Their research “does not find robust evidence that supports the claim that zero-rating leads to lower data caps”: “[T]he prevalence of zero-rating across an entire family of tariffs with varying data caps would seem to be inconsistent with a negative impact of zero-rating on caps. We do not find evidence to suggest that zero-rated tariffs within a country have lower data caps than non-zero-rated tariffs; on the contrary, in the UK O2 only offers zero-rating on its tariffs with the largest data allowances. Across our case study countries, we find that Bulgaria and Portugal have the lowest data allowances as well as the most instances of zero-rating, but on the other hand Swedish plans have very high data allowances and still include zero-rated offers.” (pp. 120-121)

They also admit that they “do not have information about tariffs across time and therefore we are not able to determine what impact zero-rating has had on data caps within countries” and that “[r]obust evidence about the strength and relevance of the various effects that are being claimed to flow from zero-rating is lacking. Some specific observations aside, there is little reliable data that would show the impact of zero-rating in the market place.” (pp. 120 and 122)

Based on these considerations, two different hypothesis on operators’ strategies and the relation between zero-rating and included data volume appear plausible to us:

- (i) Zero-rating is used by an operator to increase the value to consumers for all or certain tariffs in order to be able to charge more and to differentiate from its competitors. In this scenario, zero-rating and high data volumes are likely to be complementary.
- (ii) Zero-rating is used to incentivise consumers to use certain apps. In this case, zero-rating and data volumes are likely to be substitutes, i.e., zero-rating would *ceteris paribus* be associated with lower data volumes.

The effect could therefore go in both directions and it is an empirical question to analyse which effect dominates in particular circumstances.

Empirical studies on the effects of zero-rating are rare. The only ones we are aware of are Berglind (2016) and epicenter.works (2019). Berglind (2016) investigates the effects of zero-rating on mobile broadband adoption and claims that zero-rating can be associated with additional growth in broadband demand and increased social welfare. It is based on a quite low number of observations (17), however.

epicenter.works (2019) look at zero-rating and price developments in the EU28 countries, Norway, Iceland, Japan, Korea, Turkey, and the USA for the years 2014/15 and 2015/16. The dependent variable consists of price baskets published by the European Commission. The explanatory variables identify whether there is no zero-rating in a certain country in 2014 and 2015, there is zero-rating in 2014 but not in 2015, or there is zero-rating in 2015 and not in 2014 (with no zero-rating in both periods being the base case).⁴ They conclude that markets with zero-rating offers in both years show statistically significant lower decrease in prices than markets without zero-rating in both years (by about 10%).

Our study has been inspired by the discussion with epicenter.works and is similar to the approach in their 2019 report in that we attempt to investigate the effects of zero-rating on prices (and data-caps) by comparing developments in different countries. But we can rely – at least for the 15 countries considered – on a richer dataset (tariff-level data and more detailed information on zero-rating matched to tariffs) and a longer observation period (2015-2018, with half-yearly data).

It is also important to note that we are not investigating or do not make any statements about potential welfare effects of zero-rating. EC (2017, p. 121) states that even if zero-rating went hand in hand with lower data caps, it would be unclear whether this causes consumer harm.⁵ Also, even if zero-rating was related to higher data caps, negative effects e.g. on the CAP market (leading to a reduction of choice for consumers) could not be excluded. There is certainly need for further research in this direction.

3 Developments 2015-2018

This section first describes the different data sources we use. Then we present some statistics in order to illustrate important trends over the years 2015-2018.

3.1 Data sources

Data on mobile tariffs was purchased by RTR from Tarifica.⁶ Tarifica supplied detailed tariff data for 53 MNOs⁷ in 15 EU countries for the years 2015-2018 on a half-yearly

⁴ A country is classified as „zero-rating“ if there is at least one zero-rating offer on the market in the year considered. The “importance” of zero-rating offers (e.g. in terms of their share in all offers) is not considered.

⁵ See also Schnurr and Wiewiorra (2018) who make a similar conclusion in light of the results of their model.

⁶ see www.tarifica.com

⁷ Information is available for the main brand of each MNO. MVNOs or sub-brands of MNOs are not included.

basis.⁸ The countries are Austria, Belgium, Czechia, Denmark, Germany, Finland, France, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, Sweden, and the United Kingdom. With these countries, we cover more than 85% of the EU-28 population as well as different regions.

The tariff level data include information on the monthly fee, the one-off fee, the contract length, included data, included minutes and SMS, and on whether the tariff is a pre- or post-paid tariff. From the tariff names and the contract length, we can also infer whether a handset is included (but not the amount of the handset subsidy). It also includes information on additional plan features, in particular also on zero-rating features. For the 15 countries and the four years, we have more than 11.000 observations of 'smartphone tariffs' (tariffs with included mobile data and minutes or SMS).

In this study, we focus on smartphone tariffs available to new subscribers in the residential segment. Pure data tariffs (without included minutes or SMS) and business tariffs are not considered. Also, we do not have any information on the actual usage (e.g. number of customers or number of new customers) for the individual tariffs nor any information about the actual use of zero-rating apps or options. Such data comparable across several countries are not available to our knowledge.

In order to check and complete the information on zero-rating, RTR has compiled in addition an own zero-rating database for the 15 countries. It is mainly based on:

- Information from European Commission (2017), a study which covers zero-rating practices amongst others in Germany, Portugal, Sweden and the United Kingdom in the years up to 2016;
- Information from a database collected by epicenter.works⁹ in the second half of 2018 with detailed information on zero-rating offers in all EU countries;
- Web research;
- Information from other national regulatory authorities (NRAs) for electronic communications.¹⁰

This zero-rating database includes the following information on zero-rating offers:

- The period the offer was on the market;
- Whether the offer was optional or included for certain tariffs;
 - o If optional, the tariffs it could be used with;
 - o If included, the tariffs where it was included;

⁸ For 25 operator-period combinations (out of 424), the number of tariffs is very low (<5) or certain tariffs (e.g. prepaid tariffs) seemed to be missing. In these cases, we imputed tariff information from a neighbouring period. We run robustness checks to see if this imputation influences our results.

⁹ see <https://epicenter.works/document/1521>

¹⁰ A preliminary version of the database was sent out to the NRAs of the 15 countries included in the study, and almost all NRAs replied and corrected/completed the dataset as necessary. We would like to take this opportunity to thank them for their efforts.

- The type of apps it includes, assigned to the following categories: Social (including social networks and chat apps), music, video, and other (e.g. maps, cloud storage or games).

Other data we use are:

- Gross domestic product (GDP) growth as control variable whenever the dependant variable is price or price per GB (demand proxy; source: Eurostat);
- Mobile termination rates (MTRs) also as control variable whenever the dependant variable is price or price per GB (cost proxy; source: BEREC Reports);¹¹
- MNO Market shares to calculate weights for the regression (source: BEREC Termination Rates Reports¹² and publicly available information, e.g. annual reports);
- Inflation to calculate real prices (source: Eurostat);
- Exchange rates to calculate Euro prices for non-Euro countries (source: Eurostat)
- The number of MNOs as potential explanatory variable (source: publicly available information)

For the statistics presented in the following sections, we use the same sample restrictions as we use in our estimations. These restrictions are:

- The maximum price per month (including the one-off fee spread over 24 months) is limited to €100. There are only few outliers beyond this value and we believe that tariffs with such a high price have a very low probability to be chosen.
- The minimum price per month is €2. Smartphone tariffs with a lower monthly fee are considered implausible.
- The minimum of included data is 100 MB (= 0.1 GB). Below this level, we would not consider a tariff a smartphone tariff, which can sensibly be used for surfing the internet and/or the use of applications like social media and audio or video streaming.

We also run robustness checks to see how our results are influenced by these limits.

3.2 Development of Zero-Rating Offers

The practice to offer zero-rated content or applications together with smartphone tariffs became more and more widespread in the 15 EU countries considered in the period 2015-2018. Figure 1 shows the number of operators in our sample (which includes 53 MNOs in total) offering smartphone tariffs where either zero-rating is

¹¹ See for example BEREC (2018): “Termination rates at European level January 2018”, BoR (18) 103, available at https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8162-termination-rates-at-european-level-january-2018

¹² See footnote 11.

already included in the tariff (at no extra fee) and/or zero-rating options are available which can be booked in addition to all or some tariffs for an extra (monthly) fee.

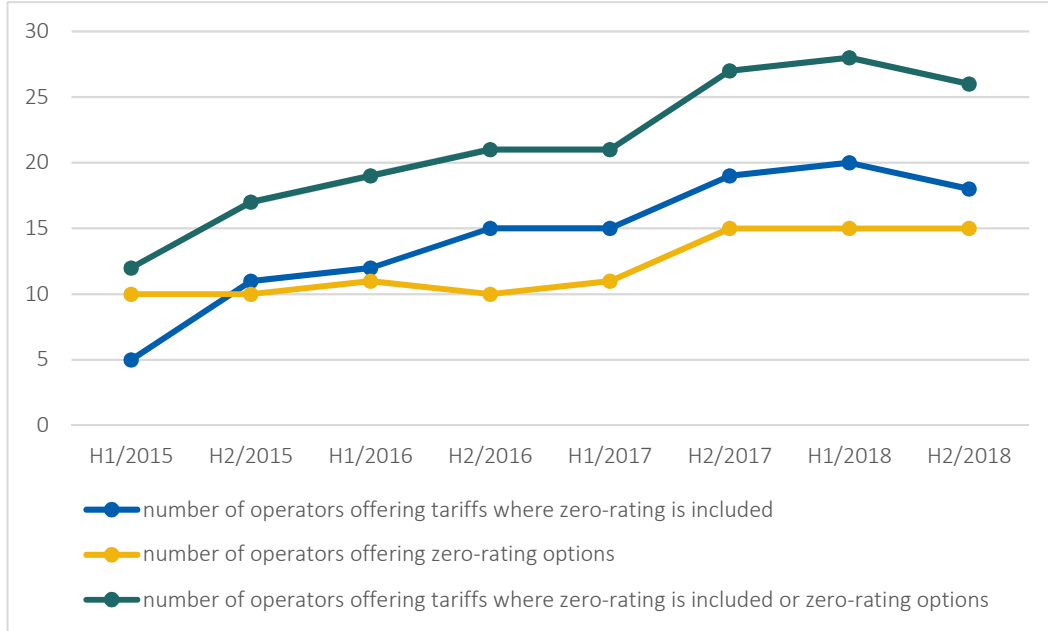


Figure 1: Number of operators (out of 53) offering zero-rating

In the first half of 2015, only five operators offered zero-rating services already included in certain tariffs. This figure rose to 20 in H1/2018. At the very end of the period considered, it dropped slightly to 18 as O2 in Czechia and Bouygues Telecom in France ceased offering such type of zero-rated services. As regards zero-rating as an option, the number of operators offering such services rose from ten in H1/2015 to 15 in H2/2018.

If both categories (included and optional) are considered, the number of operators offering such services grew from twelve in H1/2015 to 28 in H1/2018, going back to 26 in H2/2018.

Therefore, our sample includes a sufficiently large number of both, operators with and without zero-rating in order to be able to compare tariff characteristics between the two groups (see section 4.1 for our empirical approach). We also observe significant variation in the number of operators offering zero-rated services over time, which allows us to analyse the effects of the introduction or the increase/decrease of zero-rating offers on included data and prices.

Figure 4 shows the share of tariffs where zero-rating is included (at no additional costs) or where zero-rating is available as an option over time. The shares are weighted averages across MNOs (with market-shares as weights) and countries (each country weighted equally). This figures are only indicative, since they also depend to some extent on the way in which tariff information was collected (e.g. how different options for the same tariff are dealt with) which may also vary over time. Still it suggests that

the prevalence of such tariffs has an increasing trend over the period considered but is declining somewhat in H2/2018.

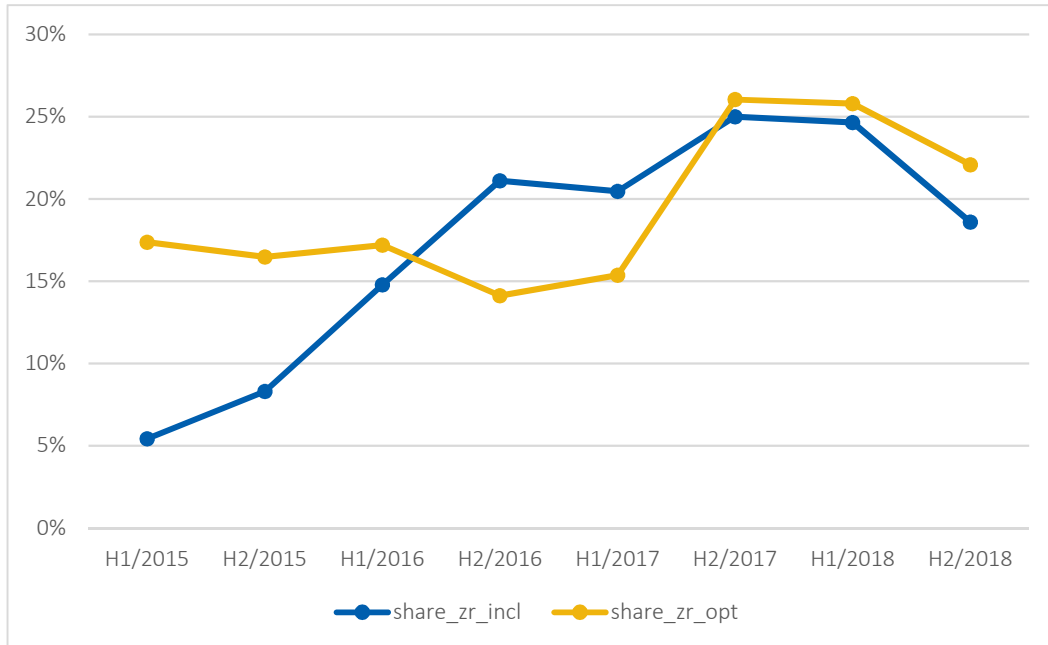


Figure 2: Share of tariffs with zero-rating included or available as option (weighted average)

The share of zero-rating offers with a certain category of app(s) included is shown in Figure 3. The following categories of applications are distinguished:

- Social (soc): Social media and chat apps (e.g. Facebook, Snapchat, WhatsApp, Twitter, Instagram, Facebook Messenger, Pinterest, Viber)
- Music (aud): Music apps (e.g. Spotify, Apple Music, Deezer, radio channels)
- Video (vid): Video apps (e.g. YouTube, Netflix, Periscope, Twitch, TV channels)
- Other (oth): E.g. maps, cloud storage, games.

Since these categories are combined in different ways, we distinguish in Figure 3 (and later in our regressions) the following types:

- only_oth, only_soc, only_aud, only_vid: Only apps (or one app) of one category are included;
- two_apps: apps from any two categories are included;
- three_four_apps: apps from any three or all four categories are included.

From H2/2016 onwards, the share of tariffs with only apps from the social category included is the highest. It increases significantly in H2/2017 to about 11% of all tariffs and then goes down to 9% in H2/2018. The share of offers with apps from two or more categories included also increases in the period 2015-2018 although at a lower level.

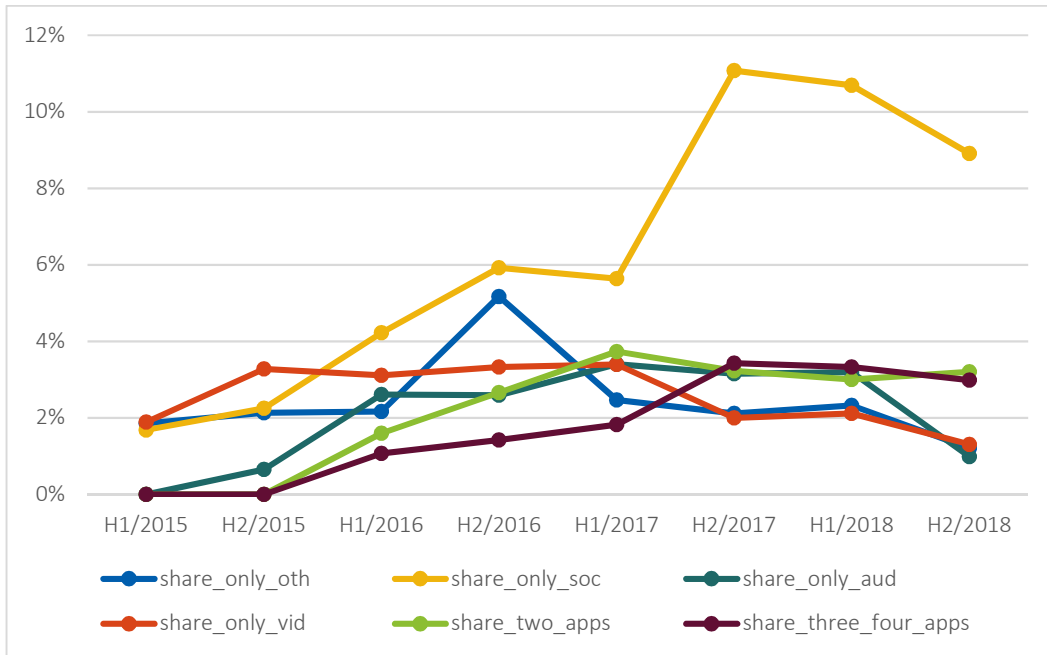


Figure 3: Share of tariffs with zero-rating of different application categories included (weighted average)

Figure 4 shows the share of tariffs where zero-rating is included across countries. It indicates that the prevalence of such tariffs varies considerably across countries and also within certain countries over time.¹³

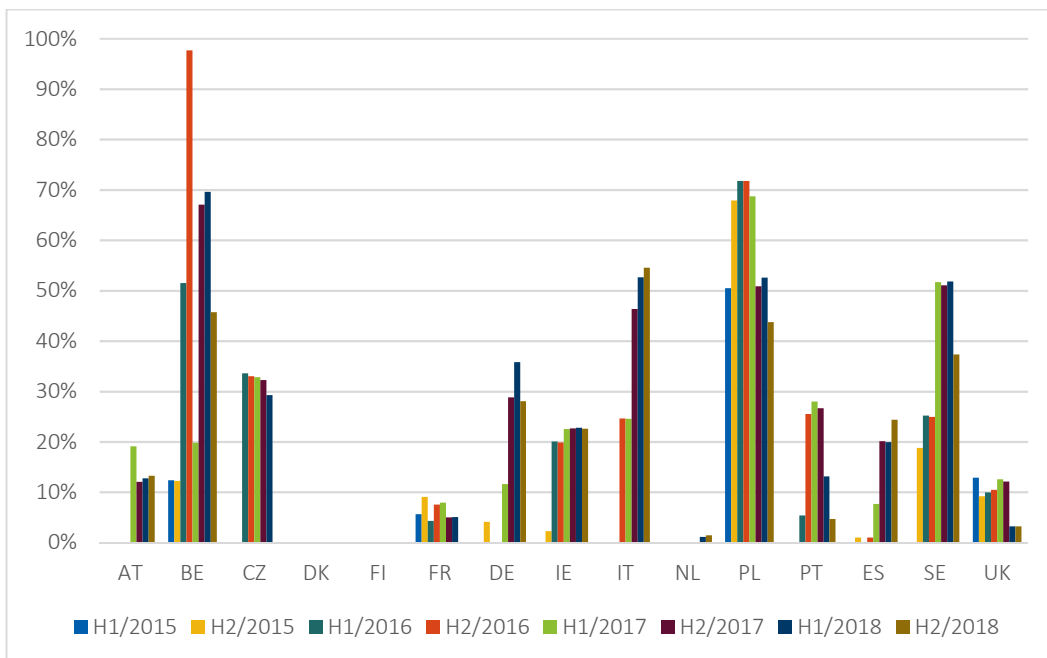


Figure 4: Share of tariffs with zero-rating included by country (market-share weighted average of MNOs)

¹³ The particularly high share in Belgium in H2/2016 is due to promotions of two MNOs, which included zero-rating for certain apps in all tariffs within this period.

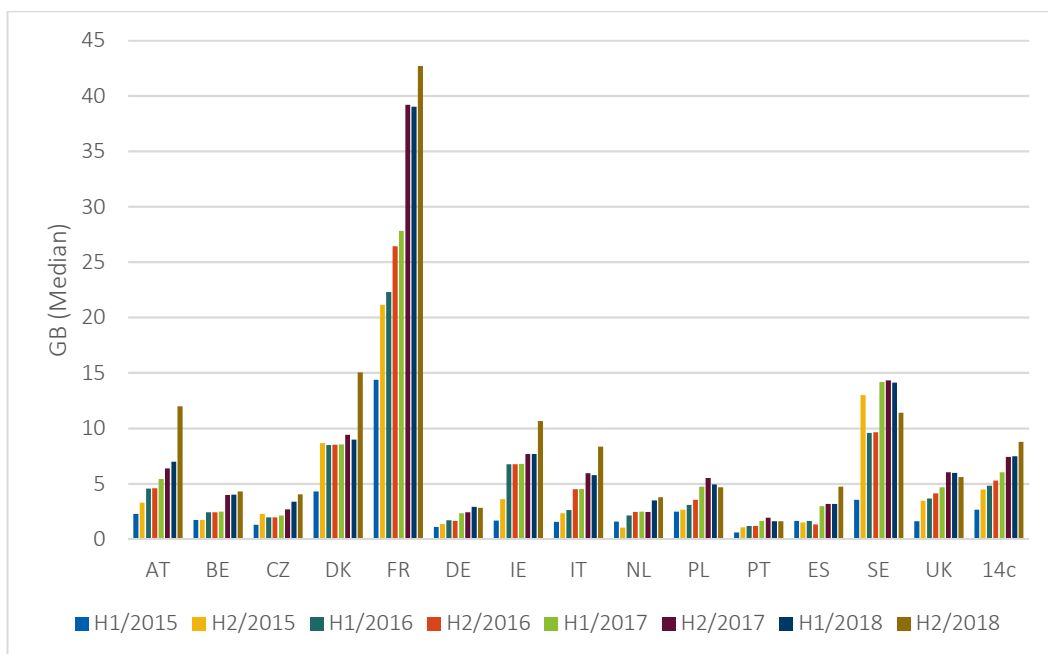
Overall, it can be concluded that the share of mobile tariffs with zero-rating included or available as option increased significantly in particular between H1/2015 and H1/2018. In H2/2018 we observe a certain decline. The share of offers with zero-rating included differs significantly across countries. Social media apps are the most popular to be zero-rated, in particular in 2017 and 2018.

3.3 Development of other tariff characteristics

In this section, we discuss the development of certain tariff characteristics, in particular the included data (data caps) and the price per Gigabyte (GB).

The development of the median of the amount of included data across all smartphone tariffs per country are shown in Figure 5. Flat rates are not included in this analysis. We also exclude operators offering primarily flat rate tariffs, since the amount of data included in the tariffs of these operators which do have a data cap is lower than the average and would give a wrong picture in comparison with other countries. Therefore, Finland (where all MNOs mainly offer flat rate tariffs) and the MNO Three (3) Ireland were excluded from the analysis.

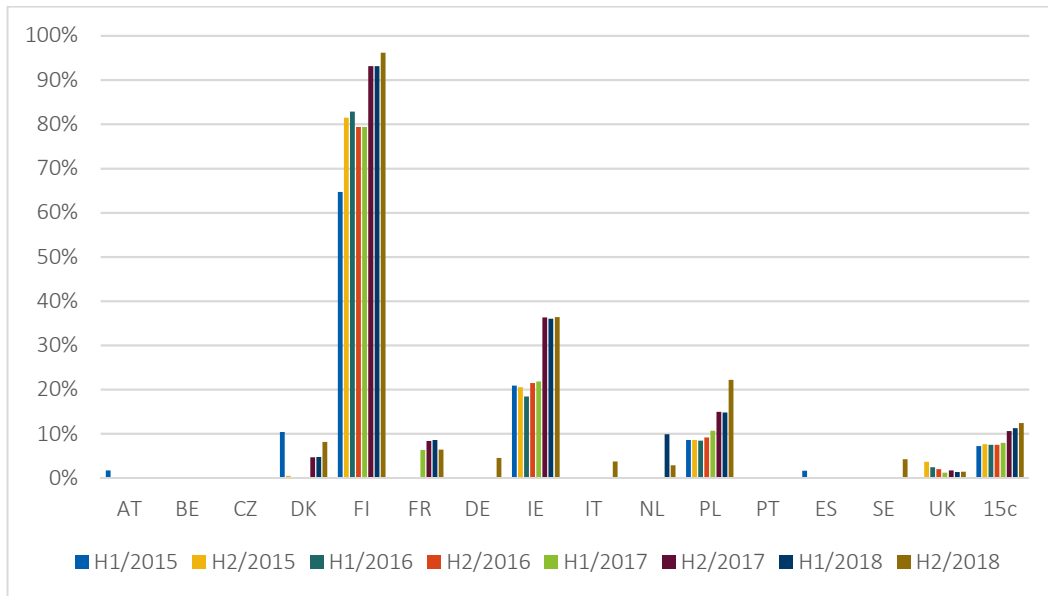
As could be expected, the average (or median) amount of included data increased significantly over the period considered. The level and the amount of the increase is quite different across countries, however. In a few countries a decline in the last periods can be observed, which can be explained to some extent by an increase in the share of flat rate tariffs (e.g. DE, PL, SE).



14c: Unweighted average over the 14 countries

Figure 5: Included data in GB (median, market share weighted average – without flat rates)

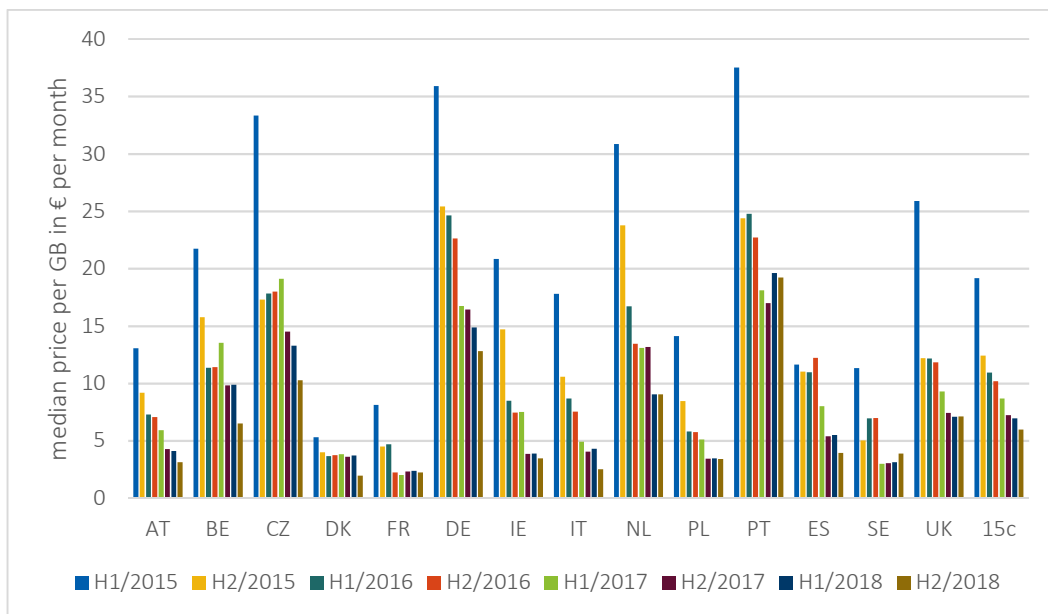
The share of flat rate tariffs also increased in several countries, with Finland having an outstanding position. Still there are several countries in which smartphone tariffs with flat rates do not play a significant role in the periods considered.



15c: Unweighted average over the 15 countries

Figure 6: Share of flat rate tariffs (market share weighted average)

Another important variable we consider in our analysis is the price per GB. Figure 7 shows that this price decreased significantly in all countries considered in the period 2015-2018. Also for this variable, the level is quite different across countries.



15c: Unweighted average over the 15 countries

Figure 7: Median price per GB (market share weighted average)

We therefore observe that while the extent of zero-rating increased in the years 2015-2018, the amount of data included and the share of flat rate tariffs increased while the price per GB decreased.

We do not yet know, however, how tariffs with zero-rating included compare to other tariffs in which zero-rating is not included. This is shown in Figure 8 - Figure 10. Again, flat rates are not considered in these figures.

We can see from Figure 8 and Figure 9 that tariffs with zero-rating included have on average a higher median value of included data and a lower price per GB. Figure 10 shows that such tariffs are, with the exception of the very first period, also more expensive than tariffs without zero-rating included. This difference becomes more pronounced in the years 2017 and 2018.

It therefore appears that zero-rating is primarily included in more expensive tariffs with a higher amount of included data and (as the price per GB decreases with the amount of included GB) a lower price per GB.

In order to analyse the difference between tariffs with zero-rating and tariffs without zero-rating more systematically, we have to control for the influence of other variables. This is done in the next section with the use of regression techniques.

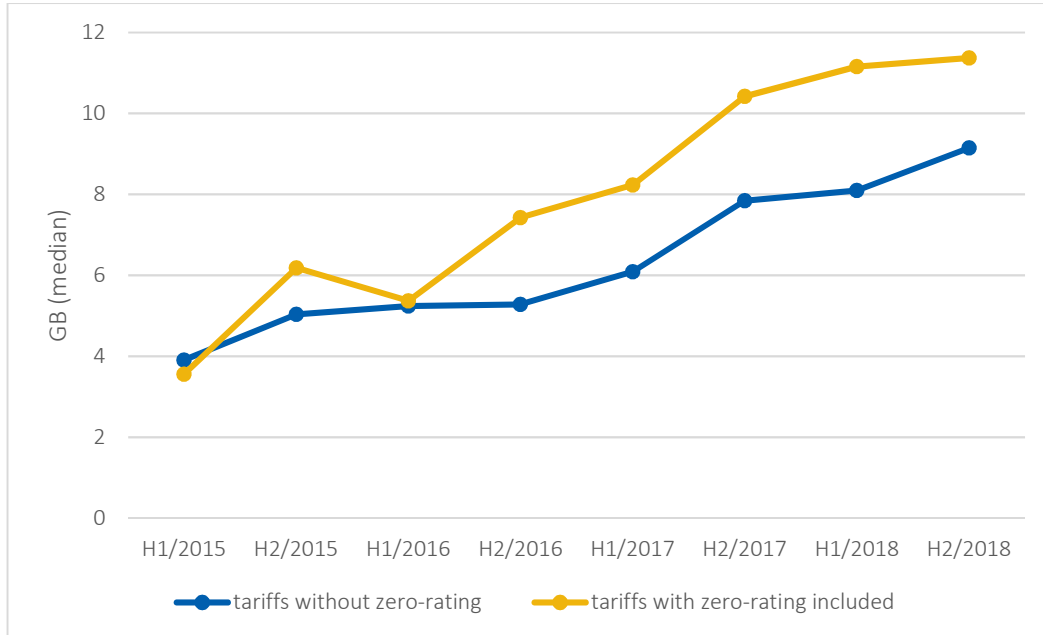


Figure 8: Included data in GB (median, market share weighted average) – tariffs with zero-rating included vs. tariffs without zero-rating included (without flat rate tariffs)

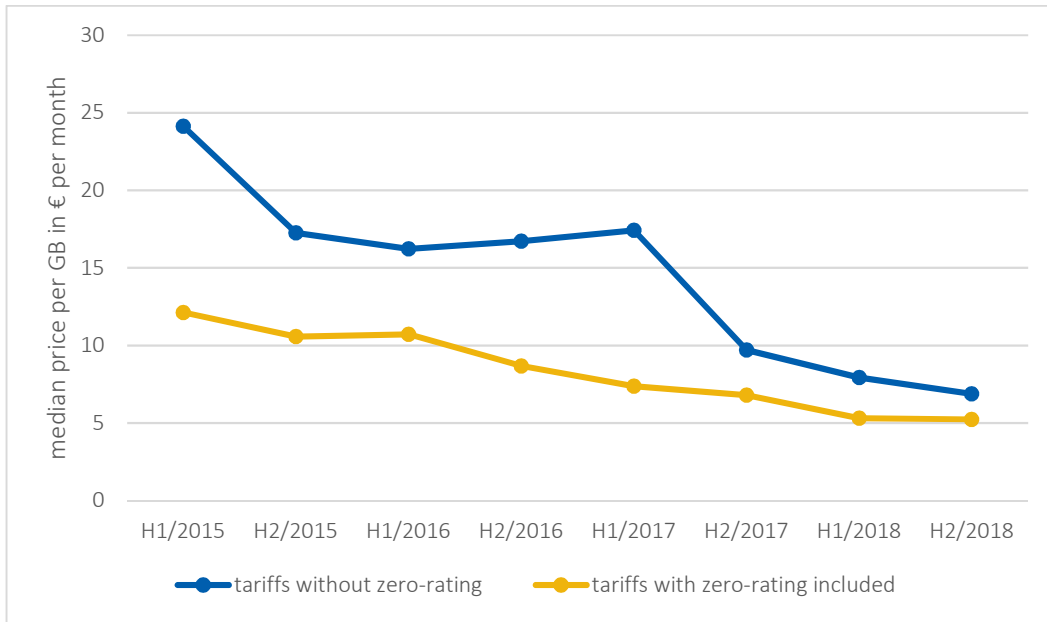


Figure 9: Median price per GB (market share weighted average) – tariffs with zero-rating included vs. tariffs without zero-rating included (without flat rate tariffs)

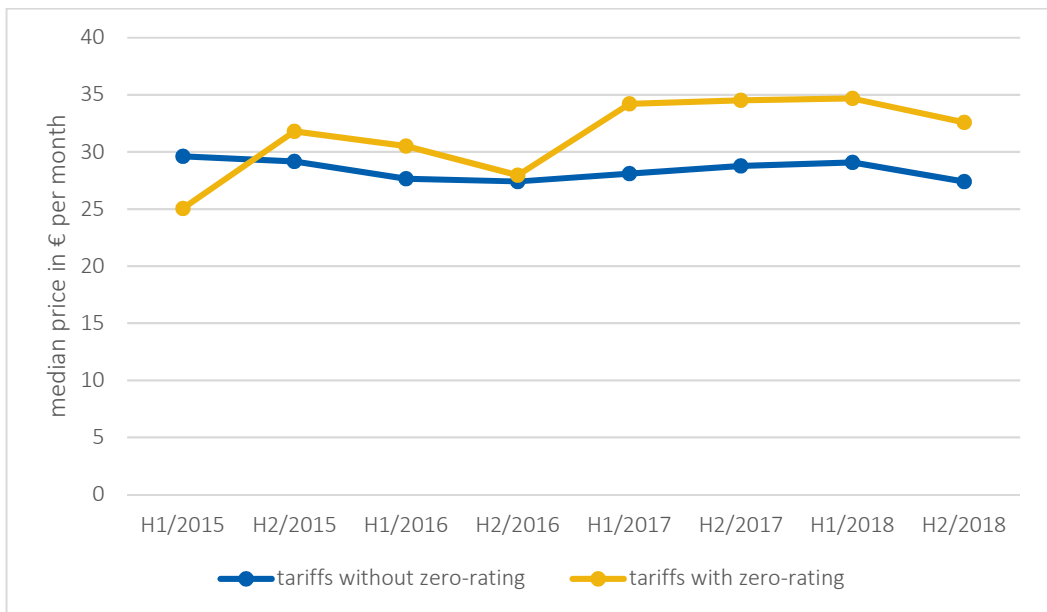


Figure 10: Median price per month (market share weighted average) – tariffs with zero-rating included vs. tariffs without zero-rating included (without flat rate tariffs)

4 Estimating the Effects of Zero-Rating

In this section, we describe our estimation approach, the variables we use and finally the results of different specifications.

4.1 Estimation approach and variables used

In order to estimate the effects of zero-rating offers on included data, the price per GB and the monthly fee of smartphone tariffs, we follow an approach which compares tariffs with zero-rating to tariffs without zero-rating while controlling for other product characteristics and, depending on the specification, demand- and cost proxies. We also control for systematic differences between operators (operator fixed effects) and allow for a flexible time trend (time fixed effects).

Since we have, for each period, a sufficient number of tariffs (and operators) with and without zero-rating, and by controlling for other influencing factors as described above, we are able to identify the effects of zero-rating offers on other tariff characteristics.

We analyse the potential effect of zero-rating on three dependent variables:

- `incl_data` (included data): The number of GB included. For flat rate tariffs, this number is approximated per country and period with twice the country-maximum of the respective period.¹⁴
- `ppgb` (price per GB): The monthly fee (including the one-off fee spread over 24 months) divided by the number of GB included (or approximated for flat rate tariffs).
- `monthly_fee`: Price per month including the one-off fee spread over 24 months.

All of these variables enter the regression in a log form. Whenever we use prices (`ppgb`, `monthly_fee`), the prices are deflated and converted into Euros for non-Euro countries with a constant nominal exchange rate (which is an average over the period considered).

Depending on the dependent variable, we use different specifications (all variables at the tariff level):

$$(1) \log(\text{incl_data}) = \alpha + \beta_i \sum_{i=1}^n z_i + \gamma \text{monthly_fee} + \delta_j \sum_{j=2}^8 t_j + \theta_k \sum_{k=2}^{53} d_k + \varepsilon$$

$$(2) \log(\text{ppgb}) = \alpha + \beta_i \sum_{i=1}^n z_i + \gamma_l \sum_{l=1}^m x_l + \delta_j \sum_{j=2}^8 t_j + \theta_k \sum_{k=2}^{53} d_k + \rho \text{GDP}_{growth} + \varphi \text{MTR} + \varepsilon$$

¹⁴ For Finland, such an approach is not possible due to the very high share of flat rates (and products without flat rates having a relatively low included volume). We therefore set included data for flat rate tariffs in Finland always to 100 GB.

$$(3) \log(\text{monthly_fee}) = \alpha + \beta_i \sum_{i=1}^n z_i + \gamma_l \sum_{l=1}^m x_l + \delta_j \sum_{j=2}^8 t_j + \theta_k \sum_{k=2}^{53} d_k + \rho \text{GDP}_{\text{growth}} + \varphi \text{MTR} + \varepsilon$$

Equation (1) represents a model for the included data as a function of other tariff characteristics (zero-rating and the monthly fee). Equations (2) and (3) represent simplified price models, where the price is a function of product characteristics, cost and demand shifters. Such price models are based on the idea that the price of a product depends on its costs and demand, but also that a product can be viewed as a bundle of attributes as in a hedonic price model.

In these specifications, z_i refers to one or several variables indicating whether a tariff has zero-rating included or available as option. The estimated coefficients β (β_i) on the zero-rating variables will give us the effect of zero-rating on included data in equation (1), the price per GB in equation (2) and the monthly fee in equation (3). We use the following zero-rating variables:

- zr_incl: A dummy variable¹⁵ identifying whether zero-rating is included in the tariff (at no additional costs). We also use interactions of zr_incl with country dummies, time dummies and country *and* time dummies;
- zr_incl_port: If zero-rating is included in any tariff of the tariff portfolio of a certain operator in a certain period, then this dummy variable identifies *all* tariffs of this operator in the respective period. The hypothesis here is that an operator adapts prices and included data for all tariffs it offers as soon as zero-rating is included in at least one of its tariffs ('portfolio approach');
- zr_incl+opt: Dummy variable identifying whether zero-rating is either included or can be optionally be added to the tariff (usually at additional monthly costs);
- zr_only_soc, zr_only_vid, zr_only_aud, zr_only_oth, zr_two_app, zr_three_four_app: Variables identifying mutually exclusive apps or groups of apps, namely social, video, audio, other, apps of any two categories, apps of any three or four categories (see also section 3.2).

In addition to zero-rating, we control for other tariff characteristics. In specification (1), explaining the included data volume, we control for the monthly fee. Not controlling for the monthly fee would result in biased coefficients if zero-rating is systematically included in more expensive tariffs which also have a higher included data volume, as suggested by the analysis reported in section 3.3.

When we use the price per GB (ppgb) as dependent variable, we use the following tariff characteristics (referred to as x_l in specifications (2) and (3)):

- incl_min: The number of included all-net minutes (in 1,000), 0 for flat rates;
- incl_min_flat: A dummy indicating whether included minutes are flat;
- incl_sms: The number of included all-net SMS (in 1,000), 0 for flat rates
- incl_sms_flat: A dummy indicating whether included SMS are flat;

¹⁵ A dummy variable has the value 1 if the condition is fulfilled and 0 otherwise.

- `with_device`: A dummy indicating whether a device is included.

If the monthly fee is the dependent variable, we include in addition:

- `incl_data`: The amount of included data (in GB), 0 for flat rates;
- `incl_data_flat`: A dummy indicating whether included data are flat.

Where the price appears in the dependent variable (`ppgb`, `monthly_fee`), we also control for GDP growth and mobile termination rates (MTRs) as proxies for demand- and cost shifters.

Equation (1) assumes that zero-rating influences the included data volume. It could be the case however that e.g. more data are included in tariffs with zero-rating (compared to tariffs without zero-rating and after having controlled for other influencing factors) or that zero-rating is added to tariffs with a higher amount of included data (or that both characteristics are determined simultaneously). This decision of operators might be influenced by characteristics unobserved to us as the econometricians leading to a potentially biased coefficient for zero-rating. The direction of the bias depends on whether zero-rating and included volume are substitutes or complements. Similarly in equations (2) and (3), unobserved characteristics may also lead to biased coefficients for zero-rating.

We therefore include fixed effects in all three equations. The variables t_j and d_k are time and operator fixed effects (dummy variables identifying operators or periods) controlling for differences in the dependent variable between operators which are constant over time and a common (flexible) time trend across all tariffs.

ϵ is the error term. In our regression, we use heteroskedasticity robust standard errors. Since standard errors might not be independent within a country, we use cluster-robust standard errors¹⁶ with clustering at the country level in a robustness check.

Summary statistics of all variables are reported in Annex 1.

Since the number of tariffs varies significantly between operators and periods, we use weights, which are proportional to the market share of an operator at a certain period divided by the number of tariffs this operator offers in this period. Since we estimate at the tariff level, all operators are weighted by their respective market shares in their home countries.

For our basket approach (see section 4.2.4), we basically use the same specification with the difference that basket values for `incl_data`, `ppgb` and `monthly_fee` are the dependent variables, we estimate on the operator level, and that tariff characteristics do not enter the regression as explanatory variables. The advantage of this approach is that we can use a panel data structure which allows us to better identify the effects

¹⁶ See e.g. Cameron and Miller (2015).

of the introduction (or reduction) of zero-rating offers over time. Each operator is weighted by its market share.

4.2 Results

We first present the results for the specifications in which we use a single zero-rating variable. Then we use specifications where we split the effect first by country and periods and then by different categories of applications and deciles of the dependent variable. All of these estimations are on the tariff level. Finally, we present results of a basket approach.

4.2.1 Single zero-rating variable

To begin with, we look at those specifications in which we use a single zero-rating variable, aggregating the effect across all periods, countries and categories of applications. Table 1 shows the results for the specifications described in section 4.1 with the dependent variables `incl_data`, `ppgb`, and `monthly_fee` and the three zero-rating variables `zr_incl`, `zr_incl_port`, and `zr_incl+opt` (each applied individually, see Table 9 in Annex 2).

In column 2 of Table 1, the amount of included data (`incl_data`, with approximations for flat rate tariffs as described in the previous section) is the dependent variable. In this specification, we control for the monthly fee¹⁷ and use operator and time fixed effects to control for differences in the dependent variable between operators which are constant over time and a common (flexible) time trend across all tariffs. The reader is referred to Table 9 in Annex 2 for the full regression results.

Even after having controlled for the gross fee, we find that tariffs with zero-rating included (variable `zr_incl`) are associated with about 22% higher data volumes than tariffs without zero-rating included. Since the dependent variable is in log form and the variable `zr_incl` is a dummy variable, the coefficient can roughly be interpreted as a percentage change in case the dummy variable goes from zero to one (i.e., if a tariff includes zero-rating).¹⁸

The effect remains at a similar level if we mark not only the tariffs with zero-rating included but the entire tariff portfolio of an operator offering tariffs which include zero-rating in a certain period (variable `zr_incl_port`, 'portfolio approach'). When we mark not only tariffs with zero-rating included but also tariffs where a zero-rating application can be added optionally (variable `zr_incl+opt`), this effect disappears. The value becomes much smaller in absolute terms and is statistically insignificant.¹⁹

¹⁷ The coefficient on the monthly fee has, as expected, a positive sign and is highly significant, indicating that tariffs with a higher monthly fee are associated with more included data.

¹⁸ The exact percentage values can be calculated by $(\exp(\text{coefficient})-1)*100$.

¹⁹ By insignificant we mean not significantly different from zero. (The null hypothesis of our test is that the coefficient is equal to zero. In this case, it cannot be rejected for conventional confidence levels.)

We are inclined to give more weight to the specifications without the options included since there is significant uncertainty to which extent such options (which usually increase the monthly price for users) are actually chosen.

In column 3 of Table 1, we show the results for the price per GB (ppgb) as the dependent variable. Here we control for further tariff characteristics as well as GDP growth and MTRs. The tariff characteristics have the expected signs (positive for with_device, negative for included minutes and SMS²⁰) and most of them are statistically significant. GDP growth and MTRs do not have a significant effect. Table 9 in Annex 2 shows the full regression results.

Regarding the signs and coefficients of the zero-rating variables with ppgb as dependent variable, they mirror the results of column 2 (where included data was the dependent variable). But this time we have negative (and significant) coefficients on the variables zr_incl and zr_incl_port indicating that tariffs with zero-rating included have on average a lower price per GB than tariffs without zero-rating. The size of the effect is almost equal to the one observed for included data, but with a negative sign. Also as observed in column 2, the effect disappears when also options are included in the zero-rating variable.

Table 1: Coefficients on the zero-rating dummy variables

	dependent variable		
	incl_data	ppgb	monthly_fee
zr_incl	0.22***	-0.23***	0.00
	(0.00)	(0.00)	(0.83)
zr_incl_port	0.19***	-0.18***	-0.04*
	(0.00)	(0.00)	(0.10)
zr_incl+opt	-0.02	-0.02	0.03
	(0.55)	(0.59)	(0.12)

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.01

With the monthly fee as dependent variable (column 4 of Table 1), there is only one relatively small statistically significant effect (at the 10%-level) for the variable zr_incl_port.

We therefore can conclude that – across all countries, periods and app categories – tariffs with zero-rating included are, holding other tariff characteristics constant, associated with a higher amount of included data and a lower price per GB, but there does not seem to be a significant difference with regard to the monthly fee.

²⁰ Tariffs with more included minutes and SMS usually also have more data included and therefore a lower price per GB (since the price increase with increasing data is usually digressive).

In the following sections, we show that the effect differs widely across countries, periods and categories of applications.

4.2.2 Effects by countries and periods

In this section, we show – for each of our dependent variables `incl_data`, `ppgb` and `monthly_fee` – the coefficients of the dependent variable `zr_incl` interacted with country dummies and time dummies. In this way, we “split” the coefficient on `zr_incl` from Table 1 in order to see by which countries or periods it is driven. The other control variables remain as in our basic specification.

Table 2 shows the coefficient on the variable `zr_incl` interacted with period dummies. With `incl_data` as dependent variable, the coefficient is always positive but statistically significant only in six of the eight periods considered. The size of the coefficient differs across periods but does not follow a clear trend over time (see also Figure 11). The results for the dependent variable `ppgb` are similar but with opposite signs. With the monthly fee as dependent variable, the coefficient is always close to zero and never statistically significant.

Table 2: Coefficients on `zr_incl` interacted with period-dummies

dep. var.	period							
	H1/15	H2/15	H1/16	H2/16	H1/17	H2/17	H1/18	H2/18
<code>incl_data</code>	0.21*	0.18*	0.30***	0.39***	0.27***	0.09	0.13	0.22**
	(0.09)	(0.10)	(0.00)	(0.00)	(0.01)	(0.36)	(0.17)	(0.02)
<code>ppgb</code>	-0.35***	-0.26**	-0.32***	-0.38***	-0.29***	-0.10	-0.12	-0.20**
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.34)	(0.25)	(0.03)
<code>monthly_fee</code>	-0.01	-0.00	-0.03	-0.04	0.04	0.04	0.02	-0.01
	(0.79)	(0.94)	(0.49)	(0.31)	(0.26)	(0.37)	(0.69)	(0.80)

p-values in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

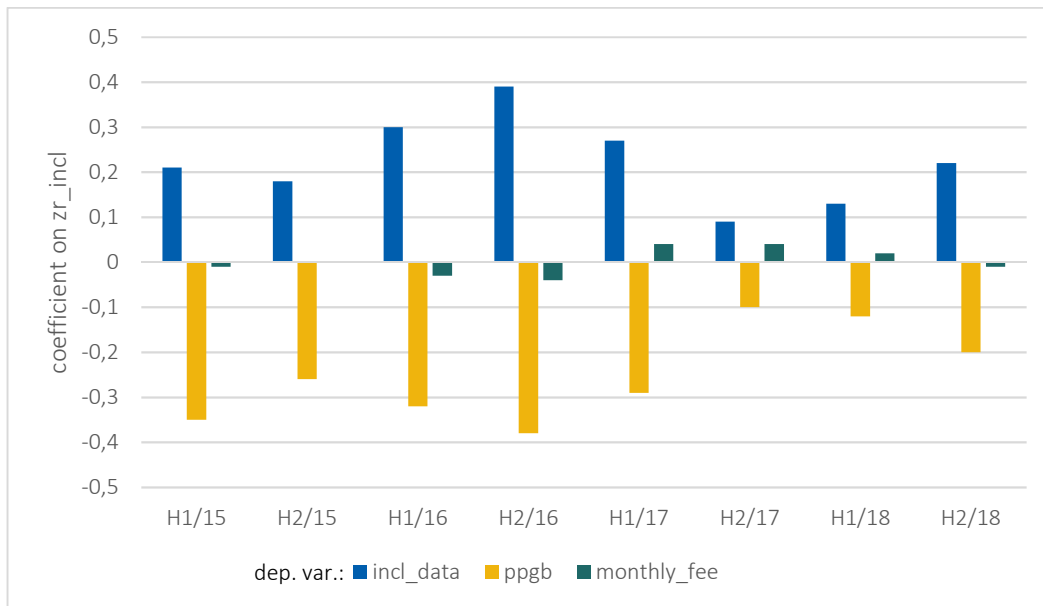


Figure 11: Coefficients on zr_incl interacted with period-dummies

If we look at the coefficients on zr_incl interacted with country dummies (see Table 3), we see that there are substantial differences across countries. Regarding the coefficients with incl_data as the dependent variable, Belgium, France, Italy, the Netherlands and Portugal show positive and significant coefficients indicating that tariffs with zero-rating included in these countries – after having controlled for the monthly fee and country level differences – are associated with higher data volumes than tariffs without zero-rating in the control group. For Poland and Czechia, on the other hand, we observe negative significant coefficients. For the other countries, there is no significant effect.²¹

With ppgb as dependent variable, the coefficient on zr_incl usually is significant for the same countries as with incl_data as dependent variable, but with the opposite sign. Also with the monthly fee as dependent variable, the coefficients on zr_incl vary significantly across countries. For several countries, a significantly negative (positive) effect of zr_incl on the price per GB (ppgb) is also associated with a significantly negative (positive) effect of zr_incl on the monthly fee. However, there are some exceptions, e.g. Austria with a significantly negative effect of zr_incl on ppgb but a significantly positive effect on the monthly fee.

In Annex 2, we show how the coefficients on zr_incl vary over time for each country (Table 10-Table 12). Only few countries have significant coefficients with the same sign over all periods (given that tariffs with zero-rating included exist, otherwise no coefficient can be estimated and the respective cells are empty). For example with incl_data as dependent variable, in France and Italy, the coefficients on zr_incl are always positive and significant²² while in Poland they are always negative and significant. In Belgium, Portugal, and Czechia, the coefficients always have the same

²¹ Denmark and Finland do not appear in the table since they do not have offers with zero-rating included.

²² Also in the Netherlands but here we have tariffs with zero-rating included only in the last two periods.

sign (positive in Belgium and Portugal, negative in the Czechia) but are not always significant. In the UK we find insignificant as well as significantly positive and significantly negative coefficients. Finally, in Austria, Germany, Ireland and Sweden, (almost) no coefficients are statistically significant. Also with `ppgb` and `monthly_fee` as dependent variable, there are several countries where the coefficients vary substantially over time.

It becomes apparent from this analysis that the effects of zero-rating can differ significantly across countries but also within a country over time. Our results also show that the effects cannot be explained by a simple classification of countries such as by the number of MNOs or the average level of included data per county (see Figure 5 in section 3.3). For France, for example, the effect of `zr_incl` on `incl_data` is significantly positive, while for Poland it is significantly negative. Both countries have four MNOs. Also, France, Belgium, and Portugal mainly exhibit positive significant coefficients on `zr_incl` (with `incl_data` as dependent variable), although France has 4 MNOs and relatively high average data volumes while Belgium and Portugal have 3 MNOs and relatively low average data volumes.

It is difficult in our view to find similarities between countries with (mainly) positive and (mainly) negative coefficients. This suggests that country-individual market specificities or operator strategies²³ are at work, which cannot easily be observed or measured.

²³ We observe that even operators belonging to the same corporate group are often adopting different strategies with regard to zero-rating in different countries.

Table 3: Coefficients on zr_incl interacted with country-dummies

country	dependent variable		
	incl_data	ppgb	monthly_fee
AT	0.04 (0.79)	-0.52*** (0.01)	0.23*** (0.00)
BE	0.29*** (0.00)	-0.19** (0.03)	-0.15*** (0.00)
CZ	-0.35** (0.02)	0.24 (0.15)	0.20*** (0.00)
DE	0.10 (0.31)	-0.07 (0.48)	0.10** (0.05)
ES	-0.17 (0.43)	0.43* (0.08)	-0.00 (0.96)
FR	1.16*** (0.00)	-1.64*** (0.00)	0.11 (0.10)
IE	0.26 (0.43)	-0.33 (0.30)	-0.01 (0.89)
IT	1.03*** (0.00)	-0.85*** (0.00)	-0.24** (0.01)
NL	1.48*** (0.00)	-0.65*** (0.00)	-0.23*** (0.00)
PL	-1.23*** (0.00)	1.03*** (0.00)	0.22*** (0.00)
PT	0.54** (0.02)	-0.53** (0.02)	-0.17* (0.05)
SE	0.19 (0.22)	-0.31 (0.12)	0.26*** (0.00)
UK	-0.13 (0.52)	0.32 (0.11)	-0.07** (0.04)

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.01

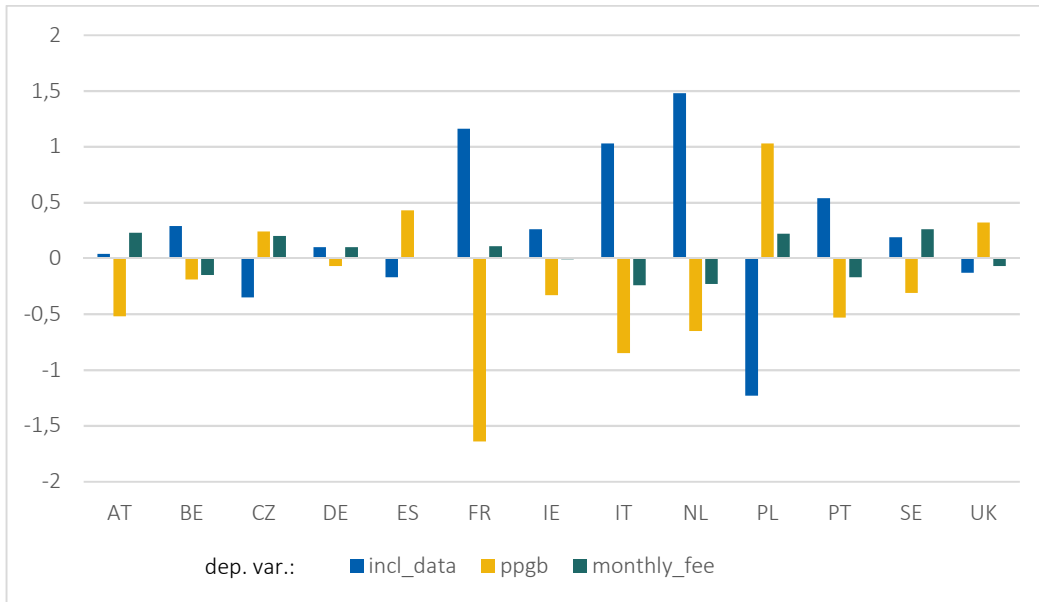


Figure 12: Coefficients on zr_incl interacted with country-dummies

4.2.3 Effects by app categories and quantiles

We now investigate – again for each of our dependent variables *incl_data*, *ppgb* and *monthly_fee* – how the coefficient on *zr_incl* varies with different categories of applications and over the distributions of the dependent variables.

In Table 4, we show how the coefficient on *zr_incl* varies with different categories of applications. The categories of applications are described in sections 3.2 and 4.1. With *incl_data* as dependent variable, we can see that the positive coefficient on *zr_incl* in Table 1 is mainly driven by tariffs with only social apps included (*zr_only_soc*)²⁴ and tariffs with two or more apps included (*zr_two_app* and *zr_three_four_app*). The coefficients on *zr_only_aud*, *zr_only_vid* and *zr_only_oth* are negative on the other hand (but insignificant with one exception). With *ppgb* as the dependent variable, the results are similar, but with opposing signs.

With the monthly fee as dependent variable, only the coefficients on *zr_only_aud* and *zr_only_vid* are significant and indicate that tariffs with only such apps included are *ceteris paribus* associated with higher prices compared to the control group.

Table 5 shows aggregated effects across all countries and periods. As we have seen above, the coefficients on *zr_incl* vary across countries and periods. The effect on the different app categories can also be expected to do so.

²⁴ *zr_only_soc* makes up the highest share of tariffs with zero-rating with 40.9%. The shares of the other app categories are: *zr_only_aud*: 11.4%, *zr_only_vid*: 19.3%, *zr_only_oth*: 8.2%, *zr_two_app*: 8.6%, *zr_three_four_app*: 11.6%.

Table 4: Coefficient on zero-rating dummies identifying different app categories

	dependent variable		
	incl_data	ppgb	monthly_fee
z_only_soc	0.35***	-0.28***	-0.05
	(0.00)	(0.00)	(0.13)
z_only_aud	-0.18*	0.18	0.12***
	(0.09)	(0.13)	(0.01)
z_only_vid	-0.20	-0.09	0.11**
	(0.17)	(0.56)	(0.04)
z_only_oth	-0.09	0.09	-0.03
	(0.46)	(0.45)	(0.65)
z_two_app	0.27**	-0.33***	0.04
	(0.01)	(0.00)	(0.32)
zr_three_four_app	0.58***	-0.59***	-0.02
	(0.00)	(0.00)	(0.71)

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.01

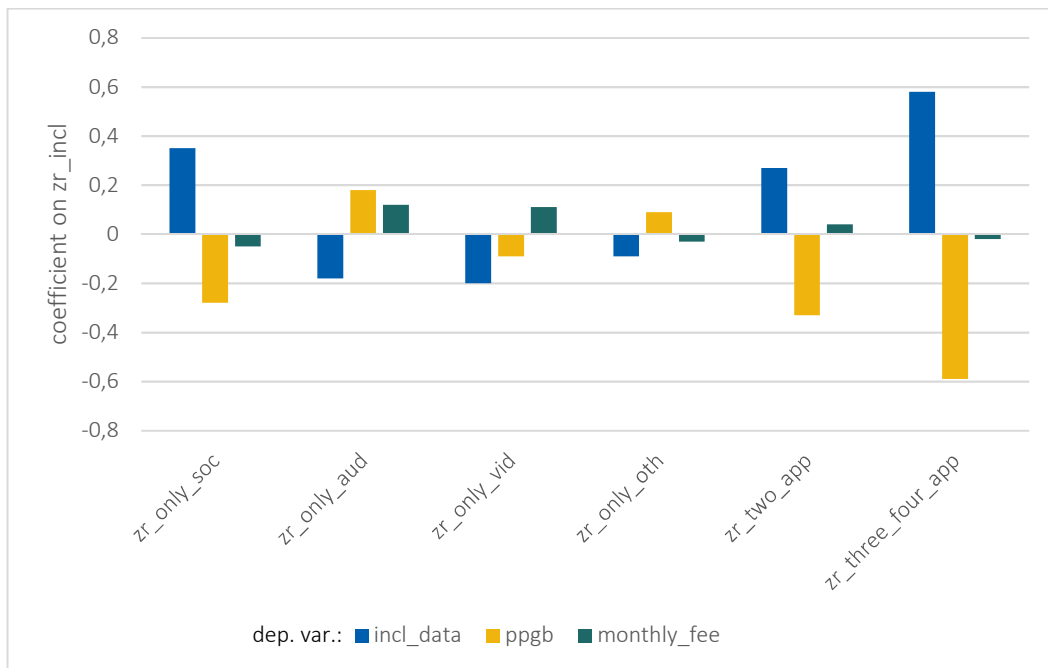


Figure 13: Coefficient on zero-rating dummies identifying different app categories

To analyse the effect of zero-rating over the distribution of the dependent variable, we use a quantile regression. The motivation is as follows: An OLS²⁵ regression estimates a linear relationship between dependent and independent variables by minimizing the sum of squared residuals, weighting residuals independent of the residual being positive or negative. Therefore, it estimates the conditional mean of the

²⁵ Ordinary least squares, our main estimation technique.

independent variable, e.g. included data, given certain values of the dependent variables. If zero-rating has a different effect across the distribution of the dependent variable, OLS coefficients might not be significant, since the positive and negative associations cancel each other out.

A quantile regression uses an asymmetric so-called loss function, which puts different weights on the residuals, depending whether they are positive or negative. This enables a more detailed analysis of the relation between the dependent and an independent variable. Table 5 provides estimations of coefficients on `zr_incl` for different quantiles of our dependent variables. We can interpret a quantile as the probability of the dependent variable being below the predicted value, conditional on certain values of the independent variables.

In quantile regression, we obtain regression coefficients for each of our quantiles of interest, for example the 10 % quantile. The coefficients of the 10 % quantile fit a model, which describes the relationships between the explaining variables and the conditional 10 % quantile of the independent variable. In case the coefficients of another quantile, e.g. the 90 % quantile, differ significantly from those of the 10 % quantile, we can infer, that the explaining variables have a different effect on the dependent variable, depending on which part of the distribution of the dependent variable we look at. For a more detailed discussion of quantile regression see Davino, Furno and Vistocco (2014) or Koenker (2005).

The coefficients on `zr_incl` in the quantile regression are shown in Table 5. With `included_data` and `ppgb` as dependent variable, we see that the coefficient on `zr_incl` varies significantly across the quantiles of the dependent variable. It declines with increasing data volumes (higher quantiles) and finally becomes insignificant for the highest two quantiles. The value of the coefficient on `zr_incl` for the 0.1 quantile, 0.54, can be interpreted as follows: The amount of included data of tariffs with zero-rating, where 10 % of the tariffs have a lower amount of included data, is significantly higher than the corresponding value of the 10 % quantile of tariffs with the same characteristics (*ceteris paribus*) without zero-rating included.

This suggests that zero-rated tariffs with a low level of included data seem to have more included data compared to the control group than tariffs with zero-rating with high levels of included data. For the price per GB it is the other way around.

With the monthly fee as dependent variable, we do not find a similarly strong trend across the deciles as for `incl_data` and `ppgb`. Still, at the lowest two quantiles, zero-rating seems to be associated with higher prices while it is associated with somewhat lower prices at the highest two quantiles.

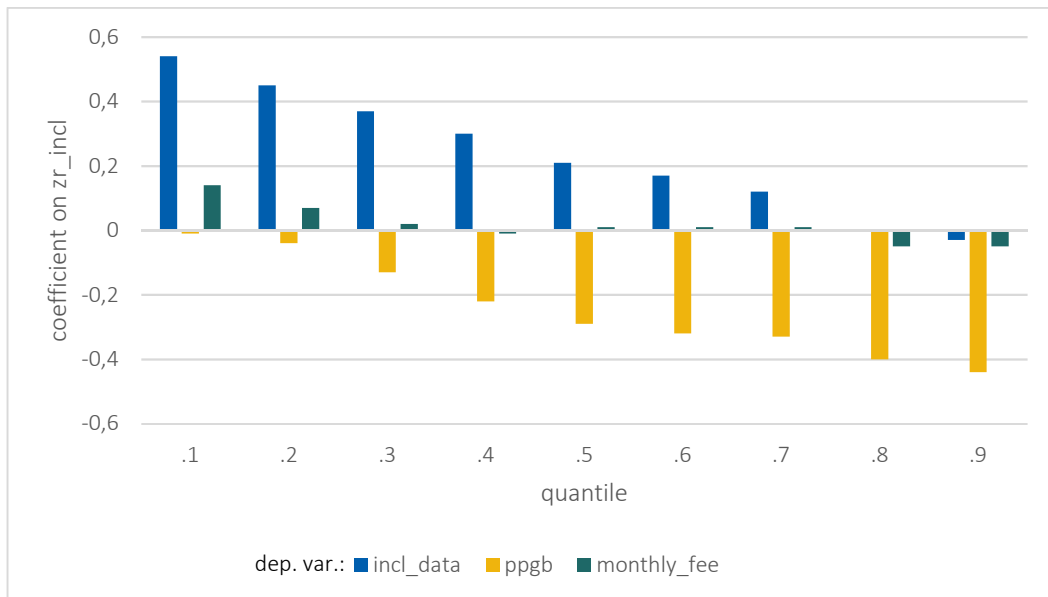
In Annex 2 we show how app categories and quantiles interact (Table 13-Table 15). We can see that also across quantiles, the coefficient on `zr_incl` is mainly driven by the coefficient on `zr_only_soc`.

Table 5: Coefficients on zr_incl by deciles (other explanatory variables as in Table 1)

dep. var.:	quantiles								
	.1	.2	.3	.4	.5	.6	.7	.8	.9
incl_data	0.54***	0.45***	0.37***	0.30***	0.21***	0.17***	0.12**	-0.00	-0.03
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.92)	(0.66)
ppgb	-0.01	-0.04	-0.13***	-0.22***	-0.29***	-0.32***	-0.33***	-0.39***	-0.44***
	(0.70)	(0.34)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
monthly_fee	0.14***	0.07***	0.02	-0.01	0.01	0.01	0.01	-0.05***	-0.05**
	(0.00)	(0.00)	(0.39)	(0.78)	(0.77)	(0.47)	(0.67)	(0.00)	(0.02)

p-values in parentheses

* p<0.10, ** p<0.05, *** p<0.01


Figure 14: Coefficient on zr_incl by deciles

We can conclude that the effect of zero-rating may not only vary across countries and periods but also across different categories of applications and the distribution of the dependent variable.

4.2.4 Basket approach

In this section, we adopt a basket approach and estimate the effects of zero-rating on our dependent variables at the operator level. This has the advantage that we get a panel data structure which allows us to better identify the effects of the introduction (or withdrawal) of zero-rating offers over time. Since we can track operators over time, this approach is close to a differences-in-differences approach which compares differences between an operator introducing zero-rating and the control group (operators without zero-rating offers) before and after the introduction of zero-rating.

The definition of the baskets is as follows:

For the basket value of the monthly fee, we take the average monthly fee of the two tariffs with the lowest monthly fee, which include at least a certain amount of data (or have a data flat rate) per operator and period. In order to account for an increasing trend of included data, we calculate a chain index in which we use 1 GB for the years 2015 and 2016 and 2 GB for the years 2017 and 2018 in the first basket ('low user') and 2 GB in 2015 and 2016 and 4 GB for 2017 and 2018 in the second basket ('high user').

For `incl_data` as dependent variable we hold the maximum monthly fee constant at a certain level (€35 for basket 1 and €50 for basket 2) and then calculate the average of the data included for the two tariffs (per operator and period) with the highest included data volume below or at this price. We use these tariffs to calculate the price per GB (`ppgb`) which we also use as dependent variable.

The resulting dataset consists of a basket value of `incl_data`, `ppgb`, and `monthly_fee` for each operator and period. Additionally, we calculate the share of zero-rated tariffs in the portfolio of each operator for each period. Therefore, our dependent variables are values on operator level, namely the share of tariffs including zero-rating (`share_zr_incl`), `zr_incl_port` (defined as above at the tariff level), and `share_zr_incl_opt` indicating the share of tariffs where zero-rating is either included or available as an option.

Each regression includes operator and time fixed effects but no other explanatory variables (except for GDP growth and MTRs with `ppgb` and `monthly_fee` as dependent variables).

Table 6 shows the coefficients on the zero-rating variables. The share of zero-rating offers included (`share_zr_incl`) does not seem to have a significant and robust effect across the different specifications. If we look at the zero-rating variable identifying the entire portfolio of an operator (`zr_incl_port`) we have similar effects as in Table 1 for `incl_data` and `ppgb` for the €50 basket. For the €35 basket there is no significant effect. Regarding the coefficients on `zr_incl_port` with the monthly fee as dependent variable, they suggest that the introduction of zero-rating in an operator's portfolio leads to a decrease in the monthly fee for the 2&4 GB basket but not for the 1&2 GB basket. Finally, if we look at the coefficients on the variable `share_zr_incl_opt`, we find that they have the same signs as for the variable `zr_incl_port` but the size and significance usually differs.

Table 6: Coefficients on the zero-rating variables with the basket approach

	dep. var.					
	incl_data		ppgb		monthly_fee	
	€35	€50	€35	€50	1 & 2 GB	2 & 4 GB
basket value	€35	€50	€35	€50	1 & 2 GB	2 & 4 GB
share_zr_incl	-0.08	0.02	0.09	-0.04	0.03	-0.10
	(0.59)	(0.88)	(0.53)	(0.78)	(0.64)	(0.19)
zr_incl_port	0.07	0.27**	-0.12	-0.28**	-0.06	-0.16**
	(0.52)	(0.02)	(0.29)	(0.02)	(0.27)	(0.01)
share_zr_incl_opt	0.31***	0.03	-0.24**	-0.11	-0.10**	-0.15***
	(0.01)	(0.77)	(0.02)	(0.18)	(0.04)	(0.00)
N	424	424	424	424	424	416

p-values in parentheses

All specifications include operator and time fixed effects

Regressions with ppgb and monthly_fee as dependent variable include GDP_growth and mtr.

* p<0.10, ** p<0.05, *** p<0.01

Overall, the results of the basket approach are qualitatively not that much different to those at the tariff level. They indicate a positive effect of the introduction of zero-rating on included data and a negative effect on the monthly fee and the price per GB. These effects are not robust across the different specifications, however.

4.2.5 Robustness checks

In Annex 3, we provide the results of the following robustness checks for the coefficients on the zero-rating variables shown in Table 1:

- (i) Changing the maximum monthly fee to €50 (instead of €100);
- (ii) Increasing the minimum of included data to 0.3 GB (from 0.1 GB);
- (iii) Increasing the minimum of included data to 0.5 GB (from 0.1 GB);
- (iv) A sample without the imputed tariffs;
- (v) Applying a Tobit model for the dependent variables incl_data and ppgb, testing the robustness of the GB values of the approximated flat rates;
- (vi) A specification with country linear trends and zero-rating variables interacted with linear country trends;
- (vii) A specification with cluster robust standard errors, clustered at the country level.

The adaptations in robustness checks (i)-(vi) do not change the qualitative results and conclusions we describe in the main part of our study.

Using cluster robust standard errors with clustering at the country level, all of the coefficients on the zero-rating variables from Table 1 become insignificant. The significance of the effect across all countries and periods is therefore not robust

against clustering of the standard errors. The results of Tables 2-5 are robust to clustering the standard errors.

5 Conclusions

In this report, we analysed the development of smartphone tariff characteristics in 15 EU countries over the years 2015-2018 with a focus on the effects of zero-rating offers on data caps and prices. We use detailed tariff data for more than 11,000 tariffs of 53 MNOs to estimate differences between tariffs with zero-rating and without.

According to our data, the importance of zero-rating increased in particular in the period 2015-H1/2018 (1st half of 2018): The number of MNOs offering tariffs which include zero-rating of certain applications (apps) grew from just five to twenty and the share of tariffs in our sample which include zero-rating from about 5% to about 25%. This share varies significantly across countries and in most countries also across time. In the second half of 2018, we see a certain decline in the share of zero-rating offers and some operators even ceased to offer such features at all.

While the share of offers including zero-rating increased, also data caps increased significantly and in several countries also the share of flat rate tariffs. A comparison between tariffs with zero-rating included and tariffs without zero-rating included shows that tariffs with zero-rating on average are more expensive, have higher data volumes included and a lower price per GB.

To analyse the differences between tariffs with and without zero-rating included in more detail, we use regression techniques to control e.g. for other tariff characteristics and systematic differences between operators and over time (operator and time fixed effects). In addition, we also apply a basket approach at the operator level, which allows us to track operators over time to see how changes in the share of offers including zero-rating of a certain operator effect other tariff characteristics.

We apply three different measures for zero-rating: Two are at the tariff level, one measuring if zero-rating is included in a certain tariff, and one measuring if zero-rating is included or available as an option. The third approach identifies all tariffs of an operator if this operator offers at least one tariff with zero-rating included at a certain point in time ('portfolio approach').

Considering the effects across all countries and periods, we do not find consistent evidence that zero-rating decreases included data volumes or increases prices per GB or monthly prices. Some of our results rather suggest that zero-rating is *ceteris paribus* associated with higher data caps and lower prices per GB. These results are, however, not robust across all of our specifications.

If we consider the effect of zero-rating on a country- and period level, we find that the direction and size of the effect (as well as its statistical significance) varies significantly across countries, but also within some countries over time. We cannot identify a

particular pattern, however (e.g. a tendency over time or on a country level the number of MNOs or high data cap vs. low data cap countries), which could help to explain or predict the effect.

When we consider different categories of apps, we find that tariffs which include only social media and chat apps or two and more app categories²⁶ usually seem to be associated with a higher amount of included data and a lower price per GB compared to tariffs without zero-rating included. For tariffs with only video or audio apps, on the other hand, it is more the other way around.

Overall, we can conclude that there does not seem to be a systematic effect of zero-rating on other tariff characteristics such as included data, price and price per GB. Rather, the effect seems to vary across countries, periods and categories of applications. Our results are therefore supportive for a case-by-case approach to the assessment of the (potential) effects of zero-rating.

Finally, we want to point out again that we limited our analysis to the effects of zero-rating on certain tariff characteristics and that we did not attempt to capture other potential effects, e.g. on the market for applications, the choice of consumers, investments, competition, or welfare. These are potential topics for future research.

²⁶ We distinguish the following app categories: Social media (including social media and chat apps), music apps (audio), video apps, and other (e.g. cloud storage, games or maps).

References

Abadie, A., Athey, S., Imbens, G. W., & Wooldridge, J. (2017). "When should you adjust standard errors for clustering?", National Bureau of Economic Research, NBER Working Paper No. 24003, available at: <https://www.nber.org/papers/w24003>.

Berglind, O. (2016): "The Effect of Zero-Rating on Mobile Broadband Demand: An Empirical Approach and Potential Implications", International Journal of Communication, 10 (2016), pp. 2442-2459.

Cameron, A. C. and D. L. Miller (2015): "A Practitioner's Guide to Cluster-Robust Inference", The Journal of Human Resources, Spring 2015 vol. 50 no. 2, pp. 317-372.

Davino, C., M. Furno and D. Vistocco (2014): "Quantile Regression: Theory and Applications", Wiley Series in Probability and Statistics.

epicenter.works (2019): "The Net Neutrality Situation in the EU. Evaluation of the First Two Years of Enforcement", available at: https://epicenter.works/sites/default/files/2019_netneutrality_in_eu-epicenter.works-r1.pdf

European Commission (2017): "Zero-rating practices in broadband markets", Report for the European Commission prepared by dot.econ, aetha, and Oswell & Vahida, available at ec.europa.eu/competition/publications/reports/kd0217687enn.pdf.

Gautier, A. and R. Somogyi (2018): "Prioritization vs zero-rating: Discrimination on the internet", CESifo Working Paper Series 7185, CESifo Group Munich, available at: http://www.lcii.eu/wp-content/uploads/2015/01/IODE4_Somogyi_PrioritizationVsZeroRating.pdf

Hoernig, S. and F. Monteiro (2018): "Zero-Rating, Network Effects, and Capacity Investments", FEUNL Working Paper Series wp627, Universidade Nova de Lisboa, Faculdade de Economia, available at: <http://fesrvsd.fe.unl.pt/WPFEUNL/WP2018/Wp627.pdf>

Howell, B. and R. Layton (2016): "Evaluating the Consequences of Zero-Rating: Guidance for Regulators and Adjudicators", August 2016, TPRC 44: The 44th Research Conference on Communication, Information and Internet Policy 2016, available at: <https://ssrn.com/abstract=2757391> or <http://dx.doi.org/10.2139/ssrn.2757391>.

Koenker, R. (2005): "Quantile Regression", Cambridge University Press.

Krämer, J. and Martin Peitz (2018): "A Fresh Look at Zero-Rating", available at: https://www.cerre.eu/sites/cerre/files/CERRE_ZeroRating_FinalReport.pdf.



Lorenzon, E. and J. V. da Cruz (2019): “Zero-Rating and Investment Incentives”, working paper presented at the 11th Paris Conference on Digital Economics, Paris, April 5-6, 2019.

Schnurr, D. and L. Wiewiorra (2018): “Bit-by-Bit Towards Unlimited: An Analysis of Zero-Rating and Sponsored Data Practices of Internet Service Providers”, 29th European Regional ITS Conference, Trento 2018 184965, International Telecommunications Society (ITS), available at: https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=EARIE45&paper_id=391

Annex 1: Summary statistics

Table 7: Summary statistics of main approach

	count	mean	sd	min	max
incl_data_approx (in GB)	11419	17.30	31.80	0.02	300.00
ppgb (in €)	11419	19.34	39.43	0.07	1501.35
monthly_fee (in €)	11419	32.16	18.19	2.07	99.73
zr_incl	11419	0.17	0.38	0	1
zr_incl_port	11419	0.26	0.44	0	1
zr_incl+opt	11419	0.32	0.47	0	1
z_only_soc	11419	0.06	0.24	0	1
z_only_vid	11419	0.03	0.16	0	1
z_only_aud	11419	0.02	0.14	0	1
z_only_oth	11419	0.02	0.16	0	1
z_two_app	11419	0.02	0.15	0	1
z_threefour_app	11419	0.02	0.13	0	1
incl_data (in GB)	11419	8.77	16.88	0	150
incl_data_flat	11419	0.09	0.29	0	1
incl_min (in thousand)	11419	0.52	3.45	0	45
incl_min_flat	11419	0.58	0.49	0	1
incl_min (in thousand)	11419	0.57	3.82	0	45
incl_sms_flat	11419	0.65	0.48	0	1
prepaid	11419	0.17	0.38	0	1
with_device	11419	0.22	0.41	0	1
GDP_growth_hy (in percent)	11419	0.01	0.03	-0.09	0.29
mtr (in €)	11419	1.04	0.43	0.42	2.60
market_share (in percent)	11419	0.32	0.09	0.03	0.50

Table 8: Summary statistics of basket approach

	Basket	count	mean	sd	min	max
incl_data_approx (in GB)	35 €	424	20.88	30.73	0.38	200
incl_data_approx (in GB)	50 €	424	27.94	33.50	1	200.00
ppgb (in €)	35 €	424	7.10	9.48	0.10	90.71
ppgb (in €)	50 €	424	4.77	5.21	0.13	35.28
monthly_fee (in €)	1 & 2 GB	424	17.07	7.56	2.40	40.99
monthly_fee (in €)	2 & 4 GB	416	22.20	10.17	3.46	65.73

Annex 2: Detailed Regression Results

Table 9: Results of the specifications with a single zero-rating variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	incl_data	incl_data	incl_data	ppgb	ppgb	ppgb	monthly_ fee	monthly_ fee	monthly_ fee
zr_incl	0.22*** (0.00)			-0.23*** (0.00)			0.00 (0.83)		
zr_incl_port		0.19*** (0.00)			-0.18*** (0.00)			-0.04 (0.10)	
zr_incl+opt			-0.02 (0.55)			-0.02 (0.59)			0.03 (0.12)
gross_fee	0.05*** (0.00)	0.05*** (0.00)	0.05*** (0.00)						
incl_data							0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)
incl_data_flat							0.48*** (0.00)	0.47*** (0.00)	0.49*** (0.00)
incl_min				-0.01** (0.02)	-0.01** (0.03)	-0.01** (0.03)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)
incl_min_flat				-0.72*** (0.00)	-0.72*** (0.00)	-0.73*** (0.00)	0.41*** (0.00)	0.41*** (0.00)	0.41*** (0.00)
incl_sms				-0.01 (0.11)	-0.01* (0.09)	-0.01* (0.08)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)
incl_sms_flat				-0.00 (0.95)	-0.01 (0.77)	-0.01 (0.84)	0.20*** (0.00)	0.20*** (0.00)	0.20*** (0.00)
with_device				0.12*** (0.00)	0.11*** (0.00)	0.11*** (0.00)	0.33*** (0.00)	0.33*** (0.00)	0.32*** (0.00)
GDP_growth				0.21 (0.79)	0.24 (0.77)	0.28 (0.72)	-0.12 (0.52)	-0.13 (0.46)	-0.11 (0.56)
mtr				0.11 (0.18)	0.11 (0.17)	0.11 (0.19)	-0.01 (0.70)	-0.01 (0.76)	-0.01 (0.65)
cons	-0.68*** (0.00)	-0.67*** (0.00)	-0.69*** (0.00)	2.56*** (0.00)	2.55*** (0.00)	2.61*** (0.00)	2.92*** (0.00)	2.91*** (0.00)	2.90*** (0.00)
N	11419	11419	11419	11419	11419	11419	11419	11419	11419
adj. R-sq	0.64	0.64	0.64	0.56	0.56	0.56	0.58	0.58	0.58

p-values in parentheses

All specifications include operator and time fixed effects

* p<0.10, ** p<0.05, *** p<0.01

Table 10: Coefficients on zr_incl interacted with country- and period dummies (dep. var.: incl_data)

dep. var.: incl_data	all periods	H1/15	H2/15	H1/16	H2/16	H1/17	H2/17	H1/18	H2/18
all countries	0.22***	0.21*	0.18*	0.30***	0.39***	0.27***	0.09	0.13	0.22**
	(0.00)	(0.09)	(0.10)	(0.00)	(0.00)	(0.01)	(0.36)	(0.17)	(0.02)
AUT	0.04					-0.10	0.13	0.10	0.02
	(0.79)					(0.50)	(0.36)	(0.49)	(0.89)
BEL	0.29***	0.60***	0.20	0.33*	0.35***	0.28	0.33*	0.19	0.14
	(0.00)	(0.00)	(0.16)	(0.07)	(0.01)	(0.45)	(0.06)	(0.24)	(0.33)
CZE	-0.35**			-0.19	-0.22	-0.44**	-0.70***	-0.18	
	(0.02)			(0.36)	(0.30)	(0.04)	(0.00)	(0.58)	
DEU	0.10		-0.20			0.07	0.03	0.01	0.24
	(0.31)		(0.16)			(0.70)	(0.84)	(0.97)	(0.17)
ESP	-0.17		-0.22***		-0.37***	0.30	-0.36	-0.41	-0.02
	(0.43)		(0.00)		(0.00)	(0.14)	(0.45)	(0.40)	(0.92)
FRA	1.16***	0.74**	0.79***	1.08***	1.34***	1.13***	1.71***	1.65***	
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
GBR	-0.13	1.47***	0.34	-0.63**	-0.34	-0.32	-1.29***	-0.92***	0.45*
	(0.52)	(0.00)	(0.11)	(0.02)	(0.17)	(0.13)	(0.00)	(0.00)	(0.07)
IRL	0.26		1.89***	0.47	0.49	0.20	0.04	-0.00	0.23
	(0.43)		(0.00)	(0.28)	(0.26)	(0.63)	(0.94)	(1.00)	(0.62)
ITA	1.03***				1.52***	1.32***	0.86***	0.72***	1.18***
	(0.00)				(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
NLD	1.48***							1.57***	1.37***
	(0.00)							(0.00)	(0.00)
POL	-1.23***	-1.80***	-1.34***	-1.07***	-1.07***	-1.09***	-1.39***	-1.40***	-1.62***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
PRT	0.54**			1.13**	0.89***	0.50	0.21	0.51**	0.23
	(0.02)			(0.02)	(0.01)	(0.17)	(0.64)	(0.04)	(0.46)
SWE	0.19		0.37	0.29	0.25	0.38	0.06	0.02	0.03
	(0.22)		(0.16)	(0.41)	(0.48)	(0.12)	(0.81)	(0.94)	(0.89)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 11: Coefficients on zr_incl interacted with country- and period dummies (dep. var.: ppgb)

dep. var.: ppgb	all periods	H1/15	H2/15	H1/16	H2/16	H1/17	H2/17	H1/18	H2/18
all countries	-0.23*** (0.00)	-0.35*** (0.00)	-0.26** (0.01)	-0.32*** (0.00)	-0.38*** (0.00)	-0.29*** (0.01)	-0.10 (0.34)	-0.12 (0.25)	-0.20** (0.03)
AUT	-0.52*** (0.01)					-0.34 (0.29)	-0.61* (0.06)	-0.59* (0.09)	-0.60** (0.02)
BEL	-0.19** (0.03)	-0.57*** (0.00)	-0.21 (0.13)	-0.29 (0.11)	-0.25* (0.06)	-0.18 (0.56)	-0.25 (0.16)	-0.07 (0.65)	0.03 (0.79)
CZE	0.24 (0.15)			0.08 (0.74)	0.10 (0.65)	0.30 (0.19)	0.55** (0.01)	0.17 (0.65)	
DEU	-0.07 (0.48)		-0.06 (0.88)			-0.32** (0.01)	0.03 (0.87)	0.09 (0.64)	-0.17 (0.30)
ESP	0.43* (0.08)		0.57*** (0.00)		0.66*** (0.00)	0.20 (0.50)	0.52 (0.37)	0.62 (0.27)	0.32* (0.09)
FRA	-1.64*** (0.00)	-1.02*** (0.00)	-1.23*** (0.00)	-1.39*** (0.00)	-1.93*** (0.00)	-1.75*** (0.00)	-2.20*** (0.00)	-2.16*** (0.00)	
GBR	0.32 (0.11)	-1.32*** (0.00)	-0.12 (0.60)	0.97*** (0.00)	0.82*** (0.00)	0.52** (0.01)	1.30*** (0.00)	0.69*** (0.01)	-0.49** (0.02)
IRL	-0.33 (0.30)		-1.36*** (0.00)	-0.66* (0.08)	-0.70* (0.06)	-0.12 (0.77)	0.03 (0.95)	0.10 (0.84)	-0.15 (0.73)
ITA	-0.85*** (0.00)				-1.22*** (0.00)	-1.04*** (0.00)	-0.70*** (0.00)	-0.65*** (0.00)	-0.95*** (0.00)
NLD	-0.65*** (0.00)							-0.71*** (0.00)	-0.55*** (0.00)
POL	1.03*** (0.00)	1.46*** (0.00)	1.07*** (0.00)	0.93*** (0.00)	0.94*** (0.00)	0.90*** (0.00)	1.17*** (0.00)	1.18*** (0.00)	1.34*** (0.00)
PRT	-0.53** (0.02)			-1.07*** (0.01)	-0.86** (0.01)	-0.49 (0.17)	-0.21 (0.63)	-0.48** (0.05)	-0.21 (0.48)
SWE	-0.31 (0.12)		-0.38 (0.26)	-0.51 (0.28)	-0.47 (0.32)	-0.43 (0.24)	-0.15 (0.69)	-0.10 (0.79)	-0.27 (0.33)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 12: Coefficients on zr_incl interacted with country- and period dummies (dep. var.: monthly fee)

dep. var.: monthly_fee	all periods	H1/15	H2/15	H1/16	H2/16	H1/17	H2/17	H1/18	H2/18
all countries	0.00	-0.01	-0.00	-0.03	-0.04	0.04	0.04	0.02	-0.01
	(0.83)	(0.79)	(0.94)	(0.49)	(0.31)	(0.26)	(0.37)	(0.69)	(0.80)
AUT	0.23***					0.14	0.32***	0.30***	0.25***
	(0.00)					(0.14)	(0.00)	(0.00)	(0.00)
BEL	-0.15***	-0.52***	-0.43***	-0.03	-0.09	-0.21	-0.17*	-0.21**	-0.14*
	(0.00)	(0.00)	(0.00)	(0.66)	(0.38)	(0.17)	(0.08)	(0.02)	(0.07)
CZE	0.20***			0.23***	0.21**	0.30***	0.28***	-0.03	
	(0.00)			(0.01)	(0.03)	(0.00)	(0.00)	(0.81)	
DEU	0.10**		0.03			0.34***	0.05	0.06	0.13*
	(0.05)		(0.83)			(0.00)	(0.66)	(0.44)	(0.10)
ESP	-0.00		-0.57***		-0.55***	-0.01	-0.01	0.07	0.03
	(0.96)		(0.00)		(0.00)	(0.96)	(0.96)	(0.71)	(0.73)
FRA	0.11	0.10	0.19**	0.37***	0.16	0.21*	-0.21***	-0.21***	
	(0.10)	(0.47)	(0.03)	(0.00)	(0.18)	(0.09)	(0.00)	(0.00)	
GBR	-0.07**	-0.26***	-0.14***	-0.10**	-0.18***	-0.01	0.13***	0.18***	0.10
	(0.04)	(0.00)	(0.01)	(0.05)	(0.00)	(0.78)	(0.00)	(0.00)	(0.11)
IRL	-0.01		-0.31***	0.06	0.02	-0.00	-0.04	-0.09	-0.03
	(0.89)		(0.00)	(0.67)	(0.90)	(0.97)	(0.71)	(0.43)	(0.83)
ITA	-0.24**				-0.41***	-0.36***	-0.15	-0.06	-0.37***
	(0.01)				(0.00)	(0.01)	(0.32)	(0.72)	(0.00)
NLD	-0.23***							-0.27***	-0.21***
	(0.00)							(0.00)	(0.00)
POL	0.22***	0.39***	0.26**	0.11	0.16*	0.24***	0.37***	0.37***	0.28***
	(0.00)	(0.00)	(0.01)	(0.20)	(0.06)	(0.01)	(0.00)	(0.00)	(0.00)
PRT	-0.17*			-0.52***	-0.19*	-0.14	-0.16	-0.00	-0.25
	(0.05)			(0.00)	(0.07)	(0.16)	(0.14)	(0.97)	(0.13)
SWE	0.26***		0.27***	0.06	0.04	0.33***	0.32***	0.30***	0.35***
	(0.00)		(0.00)	(0.48)	(0.64)	(0.00)	(0.00)	(0.01)	(0.00)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 13: Coefficients on zr_incl interacted with app category and by deciles (dep. var.: incl_data)

dep. var.: incl_data	OLS	quantiles								
		.1	.2	.3	.4	.5	.6	.7	.8	.9
zr_incl	0.22***	0.54***	0.45***	0.37***	0.30***	0.21***	0.17***	0.12**	-0.00	-0.03
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.92)	(0.66)
z_only_soc	0.35***	0.85***	0.45***	0.45***	0.48***	0.39***	0.32***	0.25***	0.08	0.02
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.21)	(0.85)
z_only_aud	-0.18*	-0.12	0.04	0.01	-0.13	-0.11	-0.17**	-0.22**	-0.31***	-0.23
	(0.09)	(0.79)	(0.81)	(0.91)	(0.38)	(0.33)	(0.02)	(0.01)	(0.00)	(0.14)
z_only_vid	-0.20	-0.34	-0.04	0.00	-0.09	-0.20**	-0.40*	-0.24	-0.62***	-1.31***
	(0.17)	(0.64)	(0.80)	(0.97)	(0.50)	(0.05)	(0.10)	(0.18)	(0.00)	(0.00)
z_only_oth	-0.09	-0.55	0.45*	0.31***	0.13	0.04	-0.07	-0.07	-0.13*	-0.11
	(0.46)	(0.89)	(0.08)	(0.00)	(0.39)	(0.68)	(0.57)	(0.73)	(0.09)	(0.43)
z_two_app	0.27**	0.36***	0.35**	0.34***	0.36***	0.24***	0.14	0.09	-0.04	0.06
	(0.01)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.13)	(0.59)	(0.59)	(0.62)
zr_three_four_app	0.58***	1.41***	0.90***	0.63***	0.49***	0.57***	0.59***	0.47**	0.49***	0.16
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.02)	(0.00)	(0.17)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 14: Coefficients on zr_incl interacted with app category- and by quantiles (dep. var.: ppgb; other explanatory variables as in Table 1)

dep. var.: ppgb		quantiles								
	OLS	.1	.2	.3	.4	.5	.6	.7	.8	.9
zr_incl	-0.23*** (0.00)	-0.01 (0.70)	-0.04 (0.34)	-0.13*** (0.00)	-0.22*** (0.00)	-0.29*** (0.00)	-0.32*** (0.00)	-0.33*** (0.00)	-0.39*** (0.00)	-0.44*** (0.00)
z_only_soc	-0.28*** (0.00)	-0.09 (0.10)	-0.12*** (0.00)	-0.19*** (0.00)	-0.25*** (0.00)	-0.31*** (0.00)	-0.32*** (0.00)	-0.27*** (0.00)	-0.39*** (0.00)	-0.54*** (0.00)
z_only_aud	0.18 (0.13)	0.24*** (0.00)	0.27*** (0.01)	0.24* (0.05)	0.14 (0.17)	0.06 (0.60)	0.01 (0.92)	0.11 (0.55)	0.08 (0.58)	0.04 (0.66)
z_only_vid	-0.09 (0.56)	0.80* (0.08)	0.27*** (0.00)	0.13 (0.45)	-0.11 (0.48)	-0.11 (0.30)	-0.03 (0.82)	0.03 (0.87)	-0.16 (0.44)	-0.02 (0.89)
z_only_oth	0.09 (0.45)	0.08 (0.55)	0.08** (0.01)	0.06 (0.67)	-0.07 (0.31)	-0.12 (0.41)	-0.12** (0.04)	-0.14 (0.63)	-0.01 (0.97)	-0.21 (0.12)
z_two_app	-0.33*** (0.00)	-0.13 (0.37)	-0.18*** (0.00)	-0.25 (0.17)	-0.37*** (0.01)	-0.39*** (0.00)	-0.50*** (0.00)	-0.41** (0.03)	-0.63*** (0.00)	-0.54 (0.12)
z_threefour_app	-0.59*** (0.00)	-0.33*** (0.00)	-0.46*** (0.00)	-0.56*** (0.00)	-0.65*** (0.00)	-0.71*** (0.00)	-0.82*** (0.00)	-1.06*** (0.00)	-1.27*** (0.00)	-1.34*** (0.00)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 15: Coefficients on zr_incl interacted with app category- and by quantiles (dep. var.: monthly fee; other explanatory variables as in Table 1)

dep. var.: monthly fee		quantiles								
	OLS	.1	.2	.3	.4	.5	.6	.7	.8	.9
zr_incl	0.01 (0.83)	0.14*** (0.00)	0.07*** (0.00)	0.02 (0.39)	-0.01 (0.78)	0.01 (0.77)	0.01 (0.47)	0.01 (0.67)	-0.05*** (0.00)	-0.05** (0.02)
z_only_soc	-0.05 (0.13)	0.18*** (0.00)	0.05* (0.10)	-0.09*** (0.00)	-0.10*** (0.00)	-0.08* (0.08)	-0.04 (0.17)	-0.05 (0.34)	-0.13*** (0.00)	-0.22*** (0.00)
z_only_aud	0.12*** (0.01)	-0.00 (0.99)	0.10** (0.01)	0.12** (0.03)	0.10** (0.03)	0.06 (0.32)	0.12** (0.03)	0.03 (0.53)	0.05 (0.23)	0.07 (0.42)
z_only_vid	0.11** (0.04)	0.16*** (0.00)	0.13*** (0.00)	0.15*** (0.01)	0.16*** (0.00)	0.15*** (0.00)	0.08 (0.22)	0.17* (0.05)	0.09** (0.03)	-0.03 (0.46)
z_only_oth	-0.03 (0.65)	-0.07 (0.13)	-0.00 (0.99)	-0.02 (0.76)	-0.05 (0.34)	0.03 (0.93)	0.04 (0.43)	0.04 (0.72)	0.10 (0.46)	0.00 (0.94)
z_two_app	0.04 (0.32)	0.15 (0.22)	0.15 (0.10)	0.16*** (0.00)	0.14*** (0.00)	0.05 (0.12)	0.09*** (0.00)	-0.00 (1.00)	-0.04 (0.70)	0.00 (0.96)
z_threefour_app	-0.02 (0.71)	0.23*** (0.00)	0.06 (0.50)	0.08* (0.09)	-0.02 (0.68)	0.01 (0.90)	-0.05 (0.30)	0.04 (0.68)	0.00 (0.97)	-0.11** (0.03)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Annex 3: Robustness Checks

Table 16: Coefficients on the zero-rating dummy variables in the robustness checks

	Specification					
	(1)	(2)	(3)	(4)	(5)	(6)
	main	monthly_fee < 50 €	incl_data > 0.3 GB	incl_data > 0.5 GB	without imputed data	tobit
dep: incl_data						
zr_incl	0.22*** (0.00)	0.12** (0.03)	0.23*** (0.00)	0.19*** (0.00)	0.20*** (0.00)	0.12** (0.04)
zr_portfolio	0.19*** (0.00)	0.14** (0.02)	0.22*** (0.00)	0.22*** (0.00)	0.21*** (0.00)	0.14** (0.02)
zr_incl+optional	-0.02 (0.55)	-0.06 (0.19)	-0.05 (0.19)	-0.06* (0.09)	-0.02 (0.68)	-0.21*** (0.00)
dep: ppgb						
zr_incl	-0.23*** (0.00)	-0.13** (0.02)	-0.25*** (0.00)	-0.20*** (0.00)	-0.20*** (0.00)	-0.10* (0.08)
zr_portfolio	-0.18*** (0.00)	-0.14** (0.02)	-0.20*** (0.00)	-0.21*** (0.00)	-0.19*** (0.00)	-0.12** (0.05)
zr_incl+optional	-0.02 (0.59)	0.00 (0.99)	0.03 (0.51)	0.04 (0.30)	-0.03 (0.47)	0.19*** (0.00)
dep: monthly_fee						
zr_incl	0.01 (0.83)	0.02 (0.37)	-0.00 (0.99)	0.01 (0.80)	0.00 (0.84)	
zr_portfolio	-0.04 (0.10)	-0.03 (0.22)	-0.03 (0.22)	-0.03 (0.18)	-0.05* (0.06)	
zr_incl+optional	0.03 (0.12)	0.05*** (0.01)	-0.00 (0.99)	0.01 (0.80)	0.00 (0.84)	

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 16 shows the coefficients on our three zero-rating dummies for the main specification (column (1), 'main') and the robustness checks as described in section 4.2.5. The results from columns (2)-(5) show that the restrictions we applied to our dataset as well as the data imputed do not have a significant impact on our results. The size and level of significance remains comparable. Only when we use the tobit model as an alternative to take into account flat rate tariffs when incl_data and ppgb are the dependent variables, we find that the coefficient on zr_incl+opt becomes larger (in absolute terms) and statistically more significant with a different sign compared to the coefficient on zr_incl and zr_portfolio. However, as stated in section 4.2.1, this is not our preferred definition of the zero-rating variable, since there is significant uncertainty to which extent such options (which usually increase the monthly price for users) are actually chosen.

Next, we consider a specification with linear time trends. To account for the possibility that the dependent variable may follow a country linear time trend (different to the general time trend over all countries), we include such time trends in addition to the

other explanatory variables as discussed in section 4.1. We also interact the variable `zr_incl` with the country linear time trend to measure deviations from the linear trend caused by zero-rating. The coefficients on `zr_incl` interacted with the country linear time trend therefore have to be interpreted differently than in the previous tables. They are the differences in the slope between the country linear trend and the country linear trend interacted with `zr_incl`.

With a few exceptions (GBR, IRL), the sign and significance of the coefficients is comparable to those reported in Table 3. The results of our main specification can therefore be considered as fairly robust.

Table 17: Coefficients on `zr_incl` interacted with country linear trends

country	dependent variable		
	<code>incl_data</code>	<code>ppgb</code>	<code>monthly_fee</code>
AUT	-0.01	-0.06*	0.04***
	(0.60)	(0.05)	(0.00)
BEL	0.04**	-0.03	-0.02**
	(0.05)	(0.14)	(0.03)
CZE	-0.03	0.04	0.01
	(0.34)	(0.32)	(0.33)
DEU	0.02	-0.01	0.02*
	(0.34)	(0.53)	(0.07)
ESP	-0.03	0.07**	0.00
	(0.40)	(0.04)	(0.71)
FRA	0.26***	-0.36***	0.01
	(0.00)	(0.00)	(0.71)
GBR	-0.15***	0.15***	0.02***
	(0.00)	(0.00)	(0.00)
IRL	-0.15**	0.17***	-0.01
	(0.02)	(0.01)	(0.66)
ITA	0.08***	-0.03	-0.01
	(0.00)	(0.17)	(0.60)
NLD	0.18***	-0.09***	-0.02***
	(0.00)	(0.00)	(0.00)
POL	-0.12***	0.10***	0.02*
	(0.00)	(0.00)	(0.07)
PRT	0.11***	-0.12***	-0.04***
	(0.00)	(0.00)	(0.00)
SWE	0.01	-0.05	0.06***
	(0.73)	(0.16)	(0.00)

p-values in parentheses

With country linear trends

Other explanatory variables as in Table 9

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Finally, to account for potentially biased estimates of the standard errors, we provide as a robustness check in Table 18 the results with clustered standard errors. If the fixed effects do not fully eliminate a common shock, standard errors might be still within-cluster correlated (Cameron and Miller, 2015). In particular, if there is heterogeneity in the treatment effect and there is clustering in sampling, standard errors should be clustered (Abadie et al 2017). Table 18 shows the coefficients on the zero-rating

variables with country-clustered standard errors. Across all countries and periods, all coefficients become insignificant. When interacted with country dummies, the coefficients on zr_incl remain significant even with clustered standard errors, as Table 19 shows (some coefficients even are significant only with clustered standard errors).

Table 18: Coefficients on the zero-rating variables with country-clustered standard errors

	dependent variable		
	incl_data	ppgb	monthly_fee
zr_incl	0.22	-0.23	0.00
	(0.18)	(0.12)	(0.94)
zr_incl_port	0.19	-0.18	-0.04
	(0.16)	(0.13)	(0.38)
zr_incl+opt	-0.02	-0.02	0.03
	(0.88)	(0.87)	(0.64)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01

Table 19: Coefficients on the zr_incl with country-clustered standard errors – country level

	dependent variable		
	incl_data	ppgb	monthly_fee
AUT	0.04	-0.52***	0.23***
	(0.58)	(0.00)	(0.00)
BEL	0.29***	-0.19***	-0.15***
	(0.00)	(0.00)	(0.00)
CZE	-0.35***	0.24***	0.20***
	(0.00)	(0.00)	(0.00)
DEU	0.10*	-0.07	0.10***
	(0.09)	(0.33)	(0.00)
ESP	-0.17**	0.43***	-0.00
	(0.02)	(0.00)	(0.90)
FRA	1.16***	-1.64***	0.11**
	(0.00)	(0.00)	(0.03)
GBR	-0.13***	0.32***	-0.07***
	(0.01)	(0.00)	(0.01)
IRL	0.26***	-0.33*	-0.01
	(0.00)	(0.07)	(0.83)
ITA	1.03***	-0.85***	-0.24***
	(0.00)	(0.00)	(0.00)
NLD	1.48***	-0.65***	-0.23***
	(0.00)	(0.01)	(0.00)
POL	-1.23***	1.03***	0.22***
	(0.00)	(0.00)	(0.00)
PRT	0.54***	-0.53***	-0.17***
	(0.00)	(0.00)	(0.00)
SWE	0.19***	-0.31***	0.26***
	(0.01)	(0.00)	(0.00)

p-values in parentheses

Other explanatory variables as in Table 9

* p<0.10, ** p<0.05, *** p<0.01