Quality Adjustment of telecommunication services

*Options for how to deal with ever-changing tariff packages*

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## Introduction

Telecommunication services are a complicated area for measuring price development. The market is a fast evolving one concerning the underlying techniques as well as the marketing strategies. With the upcoming of smart phones, the number of minutes and SMS included in a tariff plan wasn’t that important any more but the included internet connection and amount or the cost for data transfer became more and more important.

Today’s tariff plans are advertised by the included GB and the speed of the internet connection in the basic fee. The number of included minutes and SMS are in many contracts set to infinity or almost infinity as the limits are rather high. If one wants a faster internet connection or more included data transfer volume one has to select a more expensive tariff plan.

A further distinction is made between SIM only tariff packages, where no new mobile phone is included and the monthly basic fee is quite low, and tariff packages where a new mobile phone is included and the monthly basic fee is higher. In the latter packages the phone is either free of charge or a smaller amount is charged than when buying the phone without subsidy. These two kinds of tariff plans exist alongside on the market.

Another change is seen on the prepaid market. In former times you bought a SIM card and you had to pay a certain amount in advance which could be consumed until the prepaid amount was reached. Now you can buy a prepaid tariff package that you can consume in a given period of time (e.g. a month, 30 days, 28 days). In case you do not consume the whole amount it expires and you have to pay for the next time period.

The Austrian market is dominated by three network operators (NO) and a greater number of Mobile virtual network providers (MVNP), which run no own network but use the ones of the three network operators.

## Literature overview

Telecommunication services were already a topic for price measurement in the late 90s when it became clear that mobile services are a success story for the providers and households started to consume mobile services in a significant and increasing proportion. Compared with the situation before, when the fixed line services were offered by only one monopolist and there was only a restricted variety of different tariff plans, the mobile market isn’t restricted to one provider. This opened the market for a big variety of providers, tariff plans, prices and packages. For price measurement the old methods that worked for a small number of tariff plans which were defined in a similar way did not work anymore.

The first way out of this was the method of consumer profiles with a monthly bill and constant services. To be representative for the market more than one profile was needed to stratify the consumer population in e.g. low users, medium users and high users. Most applications of consumer profiles were restricted to new and currently available tariff packages on the market although many consumers held contracts for a certain tariff package over a longer time period and were caught in the tariff package by a binding period. The next assumption is the one of the rational behaviour of the consumers, this means that a consumer chooses the cheapest tariff package that fits to his consumption behaviour instantly.

Recently some countries tested the usage of hedonic models for telecommunication services. One country that has conducted a study is Korea (Kim, Kim, 2018). They investigated on post-paid tariff plans containing included data transfer, included minutes and SMS, MVOIP, video calls and speed. The characteristics have been weighted with quantity weights defined by the relative share of smartphone users subscribing to each mobile service plan in accordance with the firms’ market share. They have tested a linear model, a log-log model and a log linear model. Though, they experimented with several functional forms and came to the conclusion that the non-linear models show a better fit to the data than linear models. Regarding the analysis of the residuals, the log-log model is the preferred one because of the higher goodness of fit; also the residuals are more normally distributed. Nevertheless, according to the authors, the results are not convincing and require further detailed research.

Another study has been conducted in Croatia (Forenbacher, Perakovic, Husnjak, 2016). The authors of the study examined post-paid mobile phone service tariffs during 2009-2013 on a monthly basis. The aim of the study was to explore the effects of quality change on pricing of mobile phone plans. They used several variables such as included minutes and SMS/MMS, included data transfer, price per minute within the network, to other networks or to fixed lines, price per SMS or MMS and price of data transfer. In order to measure price and quality changes the authors tested hedonic linear and hedonic semi-log models. The final linear hedonic model developed showed a good fit to the data, the direction and magnitude of estimated parameters seemed reasonable and the multicollinearity level and quality were quite good. Although there has been limitation of the data available the study was successful in demonstrating how hedonic modelling can be used to provide reliable price and quality indices in order to analyse relationships between mobile phone price and quality. The authors of the study give the advice for further investigation in hedonic models for mobile telecommunication services so that they could be used routinely by statistical offices for instance.

A quite recent study has been made in France (Nicolle, Grzybowski, Zulehner, 2019). The authors use hedonic price regression on mobile phone tariff plans of the leading mobile telecommunications operator in France from 2011 to 2014. The study examined tariff plans with commitment and low-cost tariff plans without commitment or mobile phone subsidy. The variables used for the model are included minutes and data transfer, unit prices for minutes, VoIP and data transfer, a fixed access to Internet, mobile phone subsidy, period of commitment, premium access to music streaming. Each tariff plan has been given a unique identifier; whenever one of the variables associated with the tariff plan changes, the tariff plan is considered to be different and obtains a new identifier. Also the tariff plans have been weighted according to the number of subscribers to each tariff plan in each month.

They found out that the launch of 4G networks was the main reason for price reduction for tariff plans with commitment. Though the launch of new technology increases competition and therefore results in lower prices. Whereas the low-cost tariff plans declined mainly at the time of entry of a new low-cost competitor. The authors of the study consider hedonic price regression as a very accurate methodology to assess price changes in telecommunication markets as the results were robust in comparison to other constructed price indices.

## Modell/ Hypotheses

The currently used method for the Austrian index is a kind of user profiles and it has many drawbacks in the current situation. It isn’t able to deal with the current development where more and more all-inclusive or almost unlimited tariff plans come on the market. With the upcoming of smartphones, the included telephony service parts become more and more unimportant and the data transfer characteristics – speed, included volume - increase in importance. In this situation always the tariff plan with the lowest basic fee is selected as the consumer profiles do not reflect the speed in the definition.

With the use of web scraped data and the possibility to have all available tariffs on the market available the question of using weighting data of the providers becomes important. At the same time, it is unfortunate that now that weighting data would be needed the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR) stopped publishing market shares of the providers. Therefore, different approaches and methods have to be tested to get an index which is representative. The main question is if weighting is needed and which would be the best option.

A further question is what kind of price measurement and quality adjustment method would be applicable and reasonable. Is the matched model approach with kind of bridged overlap an option for telecommunication services? The web scraped data contain a comprehensive description of each tariff package in kind of a data table that can be easily processed to apply the hedonic methodology. Or would a pure average price fulfil the needs of price measurement?

For quality adjustments, the characteristics which should be included in the adjustment are important. Are we able to follow these changing quality characteristics?

A very last question of this work is to see if the web scraped data are fit for our purpose and whether it could be used for a reliable index production.

## Data

For the present study web scraped data from tarife.at were taken. Tarife.at is a webpage that allows comparisons of telecommunication tariffs for private consumers. The tariff packages are updated timely. At each point in time the data include all tariff packages that are available for subscription at that time point of all Austrian providers. This means that it is not a sample but the universe of all tariff packages and providers at a particular point in time. The data start with December 2018 and were analysed for this study until December 2019. All available tariff packages for contract and prepaid were taken. The data contain the basic fee, a description of the services that are already included in the basic fee, as well as the prices for additional services, e.g. additional data transfer for roaming. Moreover, the data contain the prices and service description for additional packages, these were not analysed further at this stage.

The data are web scraped on a weekly basis with the help of R. For the current study only one week of a month is used, this is equivalent to the procedures for the HICP. As tariff packages have fixed prices within their life time or are only index linked this approach seems to be appropriate. For monitoring the scraping process, the weekly web scraping of the data is necessary to be able to react if the scraper does not work regularly or the webpage has been redesigned. This enables to react fast and repair the scraper as soon as possible. Table 1 shows the used data together with the number of rows and the number of tariff packages per month. The number of tariff packages first increases and then decreases a little bit but can be regarded as constant over time.

Table 1: Date, number of rows and number of tariffs of the web scraped data

|  |  |  |  |
| --- | --- | --- | --- |
| **Calendar week** | **Date** | **# of rows in raw data** | **# tariff packages** |
| 2 | 10.1.2019 | 8.622 | 187 |
| 6 | 7.2.2019 | 9.026 | 194 |
| 10 | 7.3.2019 | 8.850 | 190 |
| 15 | 11.4.2019 | 8.848 | 190 |
| 19 | 9.5.2019 | 8.998 | 194 |
| 24 | 13.6.2019 | 8.903 | 192 |
| 28 | 12.7.2019 | 8.994 | 194 |
| 32 | 8.8.2019 | 8.554 | 184 |
| 37 | 12.9.2019 | 6.595 | 181 |
| 41 | 10.10.2019 | 6.595 | 181 |
| 46 | 7.11.2019 | 6.595 | 181 |
| 49 | 5.12.2019 | 6.524 | 180 |

### Raw data

The raw data have been stored in R format .rds as well as in Excel-Format .xlsx to be able to import them into SAS. The data consist of four columns and the variables which are needed for analysis are the values of one of these columns. Table 2 shows a shortcut of this table. In the first column the name of the provider and the name of the tariff package are included. Each provider and each tariff package have more than one row. In the second column “characteristics” a classification/ description of the service or pricing element is included. For each tariff package each entry in the column “characteristics” is singular. The next column “value” contains the corresponding value of the characteristics for the tariff package of a certain provider. The last column “header” contains a classification of the “characteristics” into prices, included volume, contract detail, additional package or general.

Table 2: Example for the raw data file

|  |  |  |  |
| --- | --- | --- | --- |
| **Name of the package** | **Characteristics** | **Value** | **Header** |
| Provider A Tariff package 1 | Basic fee | 30€ | contract detail |
| Provider A Tariff package 1 | Included GB | 7 | Included volume |
| Provider A Tariff package 1 | Minute AT-AT | 0€ | Prices |
| Provider A Tariff package 1 | SIM-Only | No | Contract detail |
| Provider B Tariff package 2 | Basic fee | 0€ | Contract detail |
| Provider B Tariff package 2 | Included GB | 0 | Included volume |
| Provider B Tariff package 2 | Minute AT-AT | 0,2€ | Prices |
| Provider B Tariff package 2 | SIM-Only | Yes | Contract detail |
| Provider B Tariff package 2 | Text | Prepaid | General |
| … | … | … | … |

The category ‘general’ of the column ‘header’ contains alphanumeric additional or advertising information from the contract details. This information is also included in the categories contract details, included volume and prices. There the data is already in a usable format therefore the category ‘general’ is not used for further analysis.

In the category ‘included volume’ are 14 entries. The basic fee of a tariff package can include minutes, SMS and data transfer volume. The included services can be within Austria, to EU countries (calls to foreign countries) or within the EU (roaming). Moreover, the usage of the included service can be defined service by service or as a joint credit. Table 3 shows the variable names of the different included services.

Table 3: Variable names of different included services

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Data** | **Minutes** | **SMS** |
| In Austria | GB\_inkl | Min\_all\_inkl | SMS\_inkl |
| Within EU (Roaming) | GB\_EU\_inkl |  |  |
| To EU countries (foreign calls) |  | Min\_AT\_EU\_inkl | SMS\_AT\_EU\_inkl |

If the service usage is defined jointly for more than one service, e.g. 300 minutes or SMS, Table 4 shows the corresponding entries and variables.

Table 4: Description and variable name of pooled credit for joint services

|  |  |
| --- | --- |
| **Credit for joint services (Pool credit) for**  | **Variable name** |
| Minutes within (roaming) or to the EU | Pool\_guth\_Min\_EU\_inkl |
| Minutes within Austria or in the EU | Pool\_Guth\_AT\_EU\_inkl |
| Minutes or SMS within Austria | Pool\_Guth\_SMS\_Min\_AT\_ikl |
| Minutes or SMS to Austria or to EU | Pool\_Guth\_SMS\_Min\_EU\_inkl |
| Roaming – all services | Roaming\_inkl |
| Roaming – incoming or outgoing | Roaming\_Min\_inkl |
| SMS within (Roaming) or to the EU | SMS\_EU\_Z |
| SMS to Austria or to the EU | SMS\_AT\_EU\_Z |

For the analysis the variables of the pooled credits where merged or transformed in the following way:

* GB\_inkl: data volume which can be used within Austria, unit is GB
* GB\_EU\_inkl: data volume that can be used in EU (roaming), unit is GB
* Roaming\_Min\_inkl: telephony incoming or outgoing (roaming), unit is minutes
* Roaming\_min\_dummy: if the variable roaming\_min\_inkl has a value greater than 0 then it is 1, else 0
* Min\_AT\_inkl: minutes to all networks within Austria, unit is minutes

Summarizes the entries of the following variables:

Min\_all\_inkl

Pool\_Guth\_AT\_EU\_inkl

Pool\_Guth\_SMS\_Min\_AT

Pool\_Guth\_SMS\_Min\_EU\_inkl

* Min\_allin\_dummy

If the variable Min\_AT\_inkl has the entry “9999” (means unlimited minutes), then it is 1, else 0

* Min\_in\_dummy

If the variable Min\_AT\_inkl has a value greater than 0 and less than 9999, it is 1, else 0

* Min\_allin\_rest\_num

If the variable Min\_AT\_inkl has a value less 9999, then this value is outputted, else 0 (0 are all tariffs with unlimited minutes)

* Min\_EU\_inkl

Minutes from Austria into the EU

Summarizes the entries of the following variables:

Min\_AT\_EU\_inkl

Pool\_Guth\_AT\_EU\_inkl

Pool\_Guth\_SMS\_Min\_EU\_inkl

* Min\_EU\_inkl\_dummy

If the variable Min\_EU\_inkl has a value greater than 0 it is 1, else 0

* SMS\_AT\_inkl

SMS in all networks within Austria

Summarizes the entries of the following variables:

SMS\_inkl

Pool\_Guth\_SMS\_Min\_AT\_inkl

Pool\_Guth\_SMS\_Min\_EU\_inkl

* SMS\_all\_dummy

If the variable SMS\_AT\_inkl is greater than 0 then it is 1, else 0

* SMS\_EU\_inkl

SMS from Austria into the EU

Summarizes the entries of the following variables:

SMS\_AT\_EU\_inkl

SMS\_EU\_Z

Pool\_guth\_SMS\_Min\_EU\_inkl

* SMS\_EU\_dummy

If the variable SMS\_EU\_inkl is greater than 0 it is 1, else 0

Table 5 shows the entries in the category ‘prices’ where the costs of 6 additional services are listed. These variables are not used for further analysis therefore they are not explained in detail.

Six additional variables contain the prices which have to be paid when the volume which is included in the credit is used. A validation of these data showed that at the least the Zero- entries are wrong as these should only occur for unlimited tariff packages. On the one hand there are packages in the data, which have no minutes included and the prices for additional minutes are zero. Or the included minutes are limited and the prices for additional minutes are zero as well. On the other hand, there are unlimited packages with a price for additional volumes. The latter case is explainable to have a rule for any case.

Currently it is not planned to analyse the additional service costs. If there is a need for analysis this data need a plausibility check and an additional survey to get them right. In which way these data are taken into account for the effective costs is not clear and was not analysed in detail.

Table 5: Entries of the category ‘prices’

|  |  |
| --- | --- |
| **Characteristic (translated)** | **Variable name** |
| Per gigabyte or part thereof – within Austria | GB\_AT\_Preis |
| megabyte – within Autria | MB\_AT\_Preis (GB/1000 =MB\_AT\_Preis) |
| Minute – from Austria into the EU | Min\_AT\_EU\_Preis |
| Minute – within Austria | Min\_AT\_AT\_Preis |
| SMS – from Austria into the EU | SMS\_AT\_EU\_Preis |
| SMS – within Austria | SMS\_AT\_AT\_Preis |

The category ‘contract details’ contains 24 entries, which give information about additional costs and other contract relevant data. These entries are subdivided into more subcategories which can be seen in Table 6. The variable “accounting” is used for the subdivision of the data into a contract and a prepaid part. For this study only the data of the contract part are analysed. In chapter 5 the used variables from this category are explained in detail.

In the next step the data were edited in a way, that all numerical values were formatted as numerical values and alphanumeric variables stayed as they were given.

Table 6: Entries, values and new variable names for the categories ‘contract’, ‘costs’ and ‘network’

|  |  |  |
| --- | --- | --- |
| **Entry** | **Value** | **Variable** |
| **The Contract** |
| Accounting  | Contract or prepaid | Abrechnung |
| Account period (days) | Number of days | Abrechnungsperiode |
| Binding  | 0, 12 and 24month | Bindung |
| Maximum Age  | None, 11, 20, 25, 26, 29 | Altersgrenze |
| SIM-Only  | yes (no subsidized handy), no | SIM\_Only |
| **The Costs** |
| Activation (one off)  | €-value | Aktivierung |
| Adjustment validity period  | Anpassung\_Dauer |
| Connection fee (one off)  | Anschlussgebühr |
| Effective costs (for 24 month)  | Effektivkosten\_24M |
| Basic fee (per month)  | Grundgebuehr |
| Delivery costs (one off)  | Lieferkosten |
| SIM charge (per year)  | SIM\_Pauschale |
| Starter package (one off)  | Starter\_Paket |
| Web Bonus (one off)  | Web\_Bonus |
| tarife.at Special discount (one off) |  | Sonderrabatt |
| **The Network** |
| Used network  | Operator | Netz |
| LTE enabled  | Yes/no | LTE |
| Download Max.  | Mbit | Download |
| Upload Max.  | Mbit | Upload\_Max |
| Pulsing data  | KB | Daten\_Takt |
| Pulsing telephony  | 1, 1/1, 60/60, 60/30 | Tel\_Takt |
| Visual Voicemail  | (only) no | Visual\_Voicemail |
| Voice Over LTE  | Yes/no | Voice\_Over\_LTE |
| WiFi Calling  | Yes/no | WiFi\_Calling |

### Flow chart

**Import**

Import Excel File with data scraped of tarife.at

On the right side, a flow chart picture the way of the necessary steps to be undertaken in SAS for processing the data scraped of the website tarife.at.

**Sort**

Sort the list by characteristics of the tariff plans

**Unique Identifier**

Each characteristic is assigned a unique identifier

First, the data obtained by tarife.at is imported in SAS. The file contains four variables: name, characteristic, value and header. Each tariff plan has as many rows as it has characteristics. For a better processing, the file has to be adapted.

In a first step each characteristic is assigned a unique identifier. Then the table can be transposed so that the data is sorted by tariff plans. Each tariff plan is now shown in one row, the unique identifiers which are the variables of the tariff plans, have become the columns.

**Transpose**

Transpose the list so that the list is sorted by tariff plans.

Each unique identifier is now a column

**Import and Merge**

Import the list with the unique identifiers and merge it with the original file

In a next step, the variables are transformed into alphanumeric or numeric values when necessary and are brought into a homogeneous form in order to make the variables comparable.

Similar variables are merged to one variable when reasonable, other variables with insufficient values are not further used.

**Numeric/Alphanumeric**

Change the variables to numeric or alphanumeric when necessary

Then the data is split into prepaid tariff plans and tariff plans with contract. For this study only the tariff plans with contract are used.

**Merge**

Merge similar variables to one variable when reasonable

In a last step dummy variables are created with the values 1 and 0 in order to gain a better significance in regression.

**Prepaid/Contract**

Split data into prepaid tariff plans and tariff plans with contract

After those steps the data scraped from the website is prepared in a way that it can be used for regression or other evaluation methods.

**Dummies**

Dummy variables are created

## Descriptive Data Analyses

This section contains a detailed description of the web scraped data from tarife.at.

### Descriptive Analysis of the category ‘contract’

The accounting period gives the information, after which period the bill is completed or how long a credit of in the basic fee included credits is valid. For contracts the period is always one month and the entries are 30,4 days (average days of a month). For prepaid cards only in 22% of the cases the accounting period is one month. The most selected category is 30 days with 56% or 28 days in 18% of the cases. There is a minority number of cases whose account period is 15 days.

For the different account periods tarife.at computes a cost variable for the adjustment of the validity of the credits to 30,4 days. This is done to make the tariffs comparable and to adjust for a higher frequency in accounting. Currently there is a trend to shift the prepaid card to an account period of 28 days. Tarife.at states that this is similar to an 8,5% price increase and argues that the contained service has a shorter credit validity afterwards.

The binding period and the variable ‘SIM only’ have a direct relationship and can be used alternatively. SIM only means, that only the tariff but no subsidized mobile phone is taken at the beginning of the contract. The costs of subsidized mobile phones yield to higher monthly fees as well to a longer binding period until the first termination of the contract is possible (24 month).

At the beginning of the data there are 4 SIM only tariffs with a binding period of 12 months. At the end all binding periods are 0.

Table 7: Number of packages for kind of contract, length of binding period and age limit

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **month** | **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| Contract | 114 | 114 | 121 | 121 | 120 | 123 | 122 | 119 | 111 | 109 | 109 | 109 | 111 |
| **Binding period** |
| SIM only/ 0 | 74 | 73 | 76 | 72 | 73 | 79 | 79 | 80 | 70 | 68 | 68 | 67 | 70 |
| SIM only/ 12 | 4 | 4 | 4 | 4 | 4 | 3 | 3 |  |  |  |  |  |  |
| 24 month | 36 | 37 | 41 | 45 | 43 | 47 | 40 | 39 | 41 | 41 | 41 | 42 | 41 |
| **Age limit** |
| With | 13 | 14 | 18 | 19 | 18 | 17 | 16 | 15 | 15 | 16 | 16 | 16 | 16 |
| without | 101 | 100 | 103 | 102 | 102 | 106 | 106 | 104 | 96 | 93 | 93 | 93 | 95 |

For 9 contract tariffs age limits are observed. These are special tariff packages for children, youth and students. There are no age limits for prepaid packages observable. In any case within these packages with age boarders it is not possible to use the mobile phone for outgoing calls or data transfer anymore once the credit of the current month is consumed.

### Descriptive Statistics of the category ‘costs’

For the present analysis only the basic fee is of interest. The effective costs were not used for further investigation. This decision is based on the assumption that most consumers have almost no additional costs except for calls to foreign countries.

The basic fee within the contract packages is the dependent variable in the regression analysis and is therefore analysed in more detail.

Table 8: Descriptive Statistics for the basic fee and the logarithm of the basic fee

|  |  |  |
| --- | --- | --- |
| **statistic** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Basic fee** |
| N | 114 | 114 | 121 | 121 | 120 | 123 | 122 | 119 | 111 | 109 | 109 | 109 | 111 |
| Mean | 20.53 | 20.6 | 20.63 | 22.07 | 21.05 | 22.19 | 22.12 | 22.1 | 24.31 | 24.6 | 24.6 | 24.6 | 23.92 |
| Median | 17 | 17 | 17 | 18.9 | 18 | 18 | 17.5 | 17.9 | 19.9 | 19.9 | 19.9 | 19.9 | 18.99 |
| Std.dev. | 14.75 | 14.72 | 14.78 | 15.92 | 15.56 | 16.84 | 16.95 | 17.2 | 18.18 | 18.32 | 18.32 | 18.32 | 17.5 |
| Skewness | 2.11 | 2.11 | 2.11 | 2 | 2.21 | 1.94 | 1.92 | 1.88 | 1.73 | 1.71 | 1.71 | 1.71 | 1.74 |
| Kurtosis | 5.57 | 5.61 | 5.83 | 4.73 | 5.84 | 4 | 3.91 | 3.7 | 2.9 | 2.77 | 2.77 | 2.77 | 3.11 |
| Normal | .801 | .802 | .806 | .806 | .781 | .799 | .799 | .803 | .819 | .819 | .819 | .819 | .825 |
| p-value | <.0001 |
| **ln(basic fee)** |
| N | 114 | 114 | 121 | 121 | 120 | 123 | 122 | 119 | 111 | 109 | 109 | 109 | 111 |
| mean | 2.82 | 2.82 | 2.82 | 2.88 | 2.84 | 2.87 | 2.86 | 2.85 | 2.96 | 2.97 | 2.97 | 2.97 | 2.95 |
| Median | 2.83 | 2.83 | 2.83 | 2.94 | 2.89 | 2.89 | 2.86 | 2.88 | 2.99 | 2.99 | 2.99 | 2.99 | 2.94 |
| Std.dev. | 0.63 | 0.63 | 0.64 | 0.65 | 0.64 | 0.68 | 0.68 | 0.7 | 0.68 | 0.68 | 0.68 | 0.68 | 0.67 |
| Skewness | 0.11 | 0.09 | 0.09 | 0.05 | 0.14 | 0.13 | 0.16 | 0.12 | 0.11 | 0.13 | 0.13 | 0.13 | 0.14 |
| Kurtosis | 0.04 | 0.07 | -0.05 | 0.02 | 0.11 | -0.12 | -0.19 | -0.25 | -0.26 | -0.36 | -0.36 | -0.36 | -0.36 |
| Normal | .991 | .991 | .992 | .990 | .988 | .988 | .988 | .988 | .989 | .985 | .985 | .985 | .988 |
| p- value | .6468 | .6235 | .6948 | .4908 | .3764 | .3534 | .3578 | .3734 | .5443 | .2834 | .2834 | .2834 | .4287 |

The average basic fee is about 20€ and slightly increases over time. The values of skewness and kurtosis are high and positive and show that the basic fee is not normally distributed. Similar values for skewness and kurtosis can be found in papers about other products and therefore it is not surprising that the basic fee is not normally distributed. The test for normal distribution shows the same result. In all months there is a significant difference from the normal distribution for the basic fee.

Therefore, the natural logarithm of the prices was taken, as done for other goods too. As for the other products, the logarithm of the basic fee shows a normal distribution. The values for skewness and kurtosis are around zero and the test for normal distribution is not significant. Therefore, in the following hedonic analysis the logarithm of the basic fee will be taken as dependent variable.

There is another variable ‘effective costs’ in the data which sums all costs over 24 months and divides the sum by 24. This variable was not used for further analysis as the formulas used are not exactly known and plausibility checks are difficult.

### Descriptive statistics of the category ‘network’

In the variables of the network category there are qualitative as well as quantitative variables. These are important for the validation of the quality of the included services.

The variable network contains the operator who provides the services. In Austria there are three operators for the network, these are A1, Drei und Magenta (renamed from T-Mobile). Table 9 shows the number of tariff packages per provider. The most packages offer the network of Drei, followed by A1 and Magenta.

LTE (long term evolution) is a service which was introduced in 2014 and nowadays is used for all tariff packages. At the beginning of the observation period only 8 packages didn’t have LTE, in the end almost all had LTE.

At the beginning of the observation period Voice over LTE was only present for a minority of packages but the shares doubled over time. Voice over LTE is used in the 4G network and gives a better voice quality, lower power consumption and a faster connectivity compared to 2G and 3G networks.

Table 9: Number of packages per month for certain characteristics of the category ‘network’

|  |  |  |
| --- | --- | --- |
| **Variable/ Value** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Network operator** |
| A1 | 35 | 35 | 39 | 42 | 42 | 40 | 38 | 38 | 40 | 40 | 40 | 40 | 41 |
| Drei | 56 | 55 | 58 | 56 | 56 | 54 | 56 | 55 | 45 | 43 | 43 | 43 | 44 |
| T-Mobile / *Magenta* | 23 | 24 | 24 | 23 | 22 | *29* | *28* | *26* | *26* | *26* | *26* | *26* | *26* |
| **LTE** |
| Yes | 106 | 106 | 113 | 111 | 119 | 122 | 121 | 118 | 110 | 108 | 108 | 108 | 110 |
| No | 8 | 8 | 8 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Voice over LTE** |
| Yes | 17 | 17 | 17 | 30 | 30 | 32 | 32 | 32 | 34 | 34 | 34 | 34 | 34 |
| No | 97 | 97 | 104 | 91 | 90 | 91 | 90 | 87 | 77 | 75 | 75 | 75 | 77 |
| **WIFI Calling** |
| Yes | 11 | 11 | 11 | 24 | 24 | 34 | 34 | 34 | 36 | 36 | 36 | 36 | 36 |
| No | 103 | 103 | 110 | 97 | 96 | 89 | 88 | 85 | 75 | 73 | 73 | 73 | 75 |

WIFI calling is another possibility to make a phone call, for this option WLAN networks are used. Same as for Voice over LTE, at the beginning of the observation period only a minority of tariff packages enabled WIFI calling, but the shares were increasing over time.

### Included Units

This category is the most important one for the evaluation of the quality and quantity of a tariff package.

One important variable is the included GB. The data stay rather constant over time. Only one package has unlimited access to the internet in the beginning but the number is increasing over time. Two tariff packages have no data transfer included. The rest are distributed across 0.5 and 100 included GB. The peaks are around 5GB, 10GB, 20 GB and 30 GB (between 10 – 20 packages each.)

An important feature of the packages is data roaming. In no case there is an unlimited access to the internet in other countries. There are more packages without data transfer included within other countries than within Austria. The remaining entries are equivalent but lower than the ones in Austria. Comparing the averages of the included GB it can be seen that the GB volume for data roaming is lower than the volume within Austria. For both possibilities the included volume is increasing. For data roaming it’s increasing more than for access within Austria.

Table 10: Number of packages with certain amount of GB

|  |  |  |
| --- | --- | --- |
| **GB\_included** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Included GB within Austria** |
| 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 0.5-100 | 111 | 111 | 118 | 118 | 117 | 116 | 112 | 107 | 102 | 100 | 100 | 100 | 100 |
| unlimited | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 7 | 7 | 7 | 7 | 9 |
| Mean for 0.5-100 | 17.67 | 17.58 | 17.27 | 18.85 | 18.35 | 17.65 | 17.63 | 17.98 | 20.61 | 20.78 | 20.78 | 20.88 | 22.13 |
| **Included GB within EU** |
| 0 | 16 | 16 | 20 | 15 | 16 | 17 | 15 | 11 | 9 | 10 | 10 | 10 | 10 |
| 0.25-100 | 98 | 98 | 101 | 105 | 107 | 105 | 104 | 103 | 102 | 99 | 99 | 99 | 101 |
| Unlimited | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean for 0.25-100 | 9.50 | 9.73 | 9.42 | 10.63 | 11.14 | 12.33 | 12.06 | 12.02 | 13.34 | 13.74 | 13.65 | 13.65 | 13.10 |

The handling of the included minutes and SMS is more complicated as the amount is often defined jointly. One gets for instance 1000 units and these can be used either for SMS or for minutes. Moreover, it could be allowed to use them within Austria and within the EU. In the present paper the maximum value for a category is used. This means if there are 1000 units for SMS and minutes available, for minutes as well as for SMS the value of 1000 is used.

Table 11: Number of packages with certain amount of minutes within Austria included

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Included minutes** | **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| 0 | 52 | 51 | 54 | 53 | 54 | 68 | 67 | 66 | 56 | 54 | 54 | 54 | 55 |
| 100-2000 | 62 | 63 | 67 | 68 | 66 | 55 | 55 | 53 | 53 | 53 | 53 | 53 | 52 |
| Unlimited |  |  |  |  |  |  |  |  | 2 | 2 | 2 | 2 | 4 |
| **Included minutes – pooled credit added** |  |
| 0 | 7 | 7 | 7 | 3 | 4 | 4 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| 50-3000 | 45 | 45 | 52 | 53 | 57 | 56 | 58 | 58 | 50 | 47 | 47 | 47 | 48 |
| Unlimited | 62 | 62 | 62 | 65 | 59 | 63 | 61 | 58 | 59 | 59 | 59 | 59 | 60 |

When including the pool credits, the number of tariffs without included minutes is negligible. On the other hand, the tariff packages with limited minutes and unlimited minutes included increase obviously.

Table 12: Pool credit for different combinations

|  |  |  |
| --- | --- | --- |
| **Included units** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Pool Minutes within Austria and EU combined** |
| 0 | 78 | 79 | 83 | 83 | 82 | 83 | 80 | 78 | 79 | 80 | 80 | 80 | 81 |
| 50-3000 | 36 | 35 | 38 | 38 | 38 | 40 | 42 | 41 | 32 | 29 | 29 | 29 | 30 |
| Unlimited | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Pool credit for SMS and minutes within Austria** |
| 0 | 112 | 112 | 120 | 119 | 118 | 109 | 108 | 105 | 97 | 95 | 95 | 95 | 97 |
| Unlimited | 2 | 2 | 1 | 2 | 2 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **Pool credit for SMS and minutes within EU** |
| 0 | 106 | 106 | 113 | 111 | 110 | 113 | 114 | 111 | 103 | 101 | 101 | 101 | 103 |
| Unlimited | 8 | 8 | 8 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

For included limited minutes about 40 packages are added, for unlimited included minutes about 10 and starting with May about 25 packages are added. In May there is a change from minutes within Austria to pooled credits but there is no change in total included minutes.

Table 13: Number of packages with certain amount of minutes within EU included

|  |  |  |
| --- | --- | --- |
| **Included units** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| 0 | 90 | 89 | 95 | 91 | 92 | 89 | 88 | 85 | 75 | 73 | 73 | 73 | 75 |
| 50-700 | 24 | 25 | 26 | 30 | 28 | 34 | 34 | 34 | 36 | 36 | 36 | 36 | 36 |
| **Included minutes – pooled credit added** |
| 0 | 46 | 46 | 49 | 43 | 44 | 39 | 38 | 36 | 35 | 36 | 36 | 36 | 37 |
| 50-3000 | 60 | 60 | 64 | 68 | 66 | 74 | 76 | 75 | 68 | 65 | 65 | 65 | 66 |
| Unlimited | 8 | 8 | 8 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

Also for minutes into the EU the values for limited units increase after including the pool credits. At the same time the number of tariff packages without roaming minutes divides by half.

Table 14: Number of packages with certain amount of included SMS

|  |  |  |
| --- | --- | --- |
| **Units** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Included SMS** |
| 0 | 16 | 17 | 17 | 16 | 17 | 29 | 26 | 26 | 25 | 25 | 25 | 25 | 25 |
| 50-3000 | 45 | 44 | 51 | 52 | 56 | 55 | 57 | 57 | 49 | 47 | 47 | 47 | 48 |
| Unlimited | 53 | 53 | 53 | 53 | 47 | 39 | 39 | 36 | 37 | 37 | 37 | 37 | 38 |
| **Included SMS within Austria and EU** |
| 0 | 99 | 99 | 104 | 104 | 105 | 102 | 101 | 98 | 88 | 86 | 86 | 86 | 89 |
| 50-600 | 15 | 15 | 17 | 17 | 15 | 21 | 21 | 21 | 23 | 23 | 23 | 23 | 23 |
| **Pooled Credit for SMS and Minutes within Austria** |
| 0 | 112 | 112 | 120 | 119 | 118 | 109 | 108 | 105 | 97 | 95 | 95 | 95 | 97 |
| unlimited | 2 | 2 | 1 | 2 | 2 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **Pooled Credit for SMS and Minutes within EU** |
| 0 | 106 | 106 | 113 | 111 | 110 | 113 | 114 | 111 | 103 | 101 | 101 | 101 | 103 |
| unlimited | 8 | 8 | 8 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| **SMS within EU\*** |
| 0 | 88 | 88 | 91 | 91 | 94 | 86 | 85 | 81 | 73 |  |  |  |  |
| unlimited | 26 | 26 | 30 | 30 | 26 | 37 | 37 | 38 | 38 |  |  |  |  |
| **Total** | **114** | **114** | **121** | **121** | **120** | **123** | **122** | **119** | **111** | **109** | **109** | **109** | **111** |

\* “SMS within EU” since 08/2019 not available any more.

### Matched observations

For the computation of a price index it is interesting how the offer prices are evolving over time. For this purpose, the tariff packages were chained over time using the variable ‘name’ of the tariff package with some minor adjustments (e.g. correction of writing errors, …) as key variable. Table 15 shows how many tariff packages could be observed over a longer period. The majority of tariff packages are available over a longer time period which means a tariff package was present in the previous month and still is there in the following month. For the matched model approach also those tariff packages which are there for the last time are relevant. The figures for this category are not stable over time. In the month before new packages are introduced the numbers of packages available for the last time are higher. On the other hand, the numbers of packages which can be observed for the first time are fluctuating as well. For the matched model approach, they are not used in the corresponding month as they have no price for the previous month. Only rarely packages for only one month can be observed. These are very special offers which are only for a limited time span on the market (e.g. tariffs connected with newspaper subscription). In Table 15 tariffs with basic fee equal zero were not used for the following table:

Table 15: Frequency of matched tariff packages

|  |  |  |
| --- | --- | --- |
| **Category** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| Match before and after | 112 | 108 | 98 | 100 | 101 | 104 | 116 | 105 | 97 | 101 | 109 | 93 | 93 |
| Last month | 2 | 4 | 12 | 7 | 13 | 3 | 4 | 12 | 9 |  |  | 16 |  |
| First month |  | 2 | 9 | 14 | 6 | 16 | 1 | 1 | 4 | 8 |  |  | 18 |
| Only one month available |  |  |  |  |  |  | 1 | 1 | 1 |  |  |  |  |

Most of the tariff packages are available for a longer period. Between 3 and 13 were either available for the last time or for the first time in the corresponding month. There is a relation between these two categories as when old tariff packages disappear there will be new packages with different definitions on the market afterwards.

Table 16: Mean of basic fee of matched tariff packages

|  |  |  |
| --- | --- | --- |
| **Category** | **2018** | **2019** |
| **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| Match before and after | 20.69 | 20.73 | 20.97 | 20.32 | 20.95 | 20.76 | 22.57 | 23.68 | 24.83 | 25.88 | 24.6 | 24.06 | 24.06 |
| Last month | 11.53 | 19.66 | 18.95 | 32.78 | 24.98 | 17.3 | 14.94 | 10.37 | 8.08 |  |  | 27.76 |  |
| First month |  | 15.75 | 22.28 | 29.24 | 14.23 | 32.44 | 9.91 | 14.92 | 51.65 | 8.52 |  |  | 23.17 |
| Only one month available |  |  | 7.12 |  |  |  | 10.83 | 4.13 | 9.9 |  |  |  |  |

Table 16 gives an overview of the means for the different availability categories of the tariff packages over time. In March two providers have brought new tariff packages on the market. The older ones were not advertised any more. In June Magenta which is a renaming of T-Mobile appeared on the market and at the same time there were new tariff packages with new included services and prices introduced.

In light of the possible usage of the data for hedonic regression some variables were dummy coded.

Table 17: Development of relative frequencies over time for some dummy coded characteristics in %

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dummy** | **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| LTE | 93 | 93 | 93 | 92 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 | 99 |
| Network operator | 27 | 27 | 29 | 31 | 31 | 35 | 35 | 36 | 41 | 41 | 41 | 41 | 41 |
| Maximum age dummy | 11 | 12 | 15 | 15 | 14 | 13 | 13 | 13 | 14 | 15 | 15 | 15 | 14 |
| Minutes unlimited in dummy | 54 | 54 | 51 | 54 | 49 | 51 | 50 | 49 | 53 | 54 | 54 | 54 | 54 |
| Minutes included dummy | 39 | 39 | 43 | 44 | 48 | 46 | 48 | 49 | 45 | 43 | 43 | 43 | 43 |
| Minutes in EU included dummy | 60 | 60 | 60 | 64 | 63 | 68 | 69 | 70 | 68 | 67 | 67 | 67 | 67 |
| Roaming minutes included | 4 | 4 | 3 | 5 | 5 | 5 | 4 | 4 | 5 |  |  |  |  |
| SMS unlimited included dummy | 96 | 95 | 95 | 98 | 98 | 98 | 98 | 98 | 99 | 97 | 97 | 97 | 97 |
| SMS in EU included | 42 | 42 | 43 | 45 | 40 | 45 | 43 | 45 | 50 | 28 | 28 | 28 | 28 |

Almost all tariff packages use LTE. Only around 30% of the tariff packages come from network operators which run their own network, the rest are tariff packages from virtual network providers (VNP) only, which use the network of the network operators.

Maximum age is a dummy for youth and student tariffs, and can be observed for 10 - 15% of the cases. Unlimited minutes are included in 50% of the cases and in less than 50% a limited number of minutes is included. In 60% of the tariff packages minutes in the EU are included. For almost all tariffs unlimited SMS are included within Austria but only for 50% SMS are included within the EU.

Most of the variables remain unchanged during the lifetime of a package, e.g. the network operator for a tariff package or the age limit, see Table 18. The change of the GB included in the EU has to do with the changed legislation, where consumers have the right to use some of their included GB also within the EU. But although the permitted use of the GB itself changes, the name of the tariff package does not change.

Table 18: Changes of included services over lifetime/ observation period

|  |  |
| --- | --- |
| **Variable** | **% unchanged in observation period** |
| GB | 89% |
| GB\_EU | 64% |
| Age limit | 100% |
| Binding period | 98% |
| Included minutes AT | 98% |
| Included minutes EU | 98% |
| Network operators | 100% |

## Results without weighting information

This section shows the calculation and results of the different methods. It starts with the average prices of the basic fee – that is an index without quality adjustment. Then a matched model and an implicit method – a variant of bridged overlap – and different hedonic models are introduced.

### Implicit methods

Different implicit methods were tried on the data, starting from average prices without QA, a matched model index with and without bridged overlap and a time product dummy regression.

#### Index of average prices

For the index of average prices, the mean of the basic fee per month of all available tariff packages is computed. Then all resulting values are divided by the average of the month 12/2018. The resulting values are an index based on 12/2018 = 100. The results are shown in Table 19.

Table 19: Mean and index (12/2018 = 100) based on average prices

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Month** | **Mean** | **Index** | **%** |
| 2018 | 12 | 20,53 | 100,00 |   |
| 2019 | 01 | 20,60 | 100,36 | 0,4 |
| 02 | 20,63 | 100,52 | 0,2 |
| 03 | 22,07 | 107,51 | 7,0 |
| 04 | 21,05 | 102,54 | -4,6 |
| 05 | 22,19 | 108,11 | 5,4 |
| 06 | 22,12 | 107,75 | -0,3 |
| 07 | 22,10 | 107,68 | -0,1 |
| 08 | 24,31 | 118,40 | 10,0 |
| 09 | 24,60 | 119,83 | 1,2 |
| 10 | 24,60 | 119,83 | 0,0 |
| 11 | 24,60 | 119,83 | 0,0 |
| 12 | 23,92 | 116,52 | -2,8 |

% = percentage change in index values compared to previous month.

The index of average prices reacts on changes of the basic fee of the available tariffs compared to the former ones. For example, in March 2019 a special Christmas tariff ended and a new tariff with a similar name appeared on the market. The basic fee and the description of the included services differ from the former one. The index of average prices shows a price increase but doesn’t correct for the difference in included service. Similar argument holds for the increase in August 2019. At that time new tariff packages whose name include ‘unlimited’ appear on the market, which are more expensive but have more service volumes included as all other tariff packages on the market. In this situation the index of average prices shows the full price increase of the basic fee and does not adjust for the difference in the included service quality.

#### Matched Model

The matched model index only uses those tariff packages which are available in both month of comparison – the current and the previous one. Implicitly this means that there is no comparison between different tariffs packages, all price differences are explained due to quality differences.

For the matched model index only those cases play a role for the index of a month which are available in that month and in the previous one. For the cases for which the former definition applies the mean of the current and of the previous month is computed. The mean of the current month is then divided by the mean of the previous month which yields a monthly index with base previous month is equal 100. These monthly indices are then chained to a time series based on 12/2018 = 100. The result of this computation can be seen in Table 20. The index is rather stable and shows only minor price increases or decreases, the monthly rates of change are around 0%.

Problematic issues are, that tariff packages, which have the same name but their included services change over their lifetime are not adjusted for. These changes are indicated as price changes in the index. On the other hand, if the name of the tariff package changes and the included service stays the same the prices of these packages are not compared directly.

For example, the change from the T-Mobile packages to the Magenta packages is not shown in the index – neither quality adjusted or not. If there is a price change connected with the introduction of Magenta – in any direction – it is not reflected in the matched model index, neither directly or indirectly.

Table 20: Means and index (12/2018 = 100) based on matched model approach

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **month** | **Mean previous month** | **Mean current month** | **Index (12/2018 = 100)** | **%** | **# tariff packages** | **# matched cases** | **% MM** |
| 2018 | 12 |  |  | 100,00 |  | 114 |  |  |
| 2019 | 01 | 20,69 | 20,69 | 100,00 | 0,0 | 114 | 112 | 98 |
| 02 | 20,64 | 20,75 | 100,53 | 0,5 | 121 | 110 | 91 |
| 03 | 21,08 | 21,13 | 100,80 | 0,3 | 121 | 107 | 88 |
| 04 | 21,41 | 21,41 | 100,78 | 0,0 | 120 | 114 | 95 |
| 05 | 20,57 | 20,66 | 101,21 | 0,4 | 123 | 107 | 87 |
| 06 | 22,32 | 22,32 | 101,21 | 0,0 | 122 | 120 | 98 |
| 07 | 22,46 | 22,32 | 100,57 | -0,6 | 119 | 117 | 98 |
| 08 | 23,60 | 23,41 | 99,75 | -0,8 | 111 | 106 | 95 |
| 09 | 25,89 | 25,88 | 99,68 | -0,1 | 109 | 101 | 93 |
| 10 | 24,60 | 24,60 | 99,68 | 0,0 | 109 | 109 | 100 |
| 11 | 24,60 | 24,60 | 99,68 | 0,0 | 109 | 109 | 100 |
| 12 | 24,06 | 24,06 | 99,68 | 0,0 | 111 | 93 | 84 |

Contrary to the index of the average prices the monthly rates of changes of the matched model approach vary less and spread around 0%. This is expected as the basic fee of a tariff package and the corresponding included services do not vary across the lifetime of a tariff package, with a few exceptions. Quality and included service differences and connected price changes are not reflected in the matched model index but are systematically left out of the price comparison. The linking procedure by the name of the tariff package has the disadvantage that changes in the included service description are not considered. Looking at Table 18 one can see that most of the variables are relatively stable; only the variable ‘GB in EU’ lists some huge changes as a new legislation allows using included services also within the EU (roaming). An analysis in case the price changes at the same time would not have been undertaken would be interesting to do.

#### Bridged Overlap

A further variant of implicit quality adjustment methods is the bridged overlap method. In the present paper bridged overlap was done in the following way: First all price changes of all tariff packages which were available in the current and in the previous month were averaged – this is equivalent to the matched model result. If there are new tariff packages in a month the price change between the previous and the current month is imputed from the above described calculation. Table 21 gives a numerical example of the computation. There are four tariff packages; tariff package D is new on the market in the second month. First the average prices for the tariff package A to C for both months are computed and the one of the current month is divided by the one of the previous month. This factor gives the price change of all packages available in both months, this is equal to the matched model approach. For tariff package D the price of the current month is divided by this factor to get an estimated price for the package in the previous month.

Table 21: Numerical example for bridged overlap

|  |  |  |  |
| --- | --- | --- | --- |
| **Tariff package** | **Previous month** | **Current month** | **Change factor** |
| A | 10,00 | 10,00 |  |
| B | 9,90 | 10,50 |  |
| C | 21,00 | 21,00 |  |
| mean A-C | 13,63 | 13,83 | 1,015 |
| D | =15/13,83\*13,63=14,78 | 15.- |  |
| Mean A – D incl.estimate | 13,92 | 14,13 | 1,015 |

Table 22 shows the results of the bridged overlap method for the entire dataset. It turns out that the matched model with bridged overlap has the same development as the matched model index itself. This is not very surprising as the estimated bridge is the price change of the matched cases and therefore there is no influence observable when a new package is introduced. As for the other implicit methods the bridged overlap method does not show any price difference when tariff packages with sales prices disappear. As the new packages have different names and different contents, they are not matched and the price difference is estimated as almost zero.

Table 22: Means and index (12/2018 = 100) based on bridged overlap

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | **Mean previous month** | **Mean current month** | **Bridge factor** | **Index (12/2018 = 100)** | **%** | **# matched cases** | **% MM** |
| 2018 | 12 |  |  |  | 100,00 |  |  |  |
| 2019 | 01 | 20,60 | 20,60 | 1,000 | 100,00 | 0,0 | 114 | 100 |
| 02 | 20,75 | 20,86 | 1,005 | 100,53 | 0,5 | 118 | 98 |
| 03 | 22,01 | 22,07 | 1,003 | 100,80 | 0,3 | 121 | 100 |
| 04 | 21,05 | 21,05 | 1,000 | 100,78 | 0,0 | 120 | 100 |
| 05 | 22,10 | 22,19 | 1,004 | 101,21 | 0,4 | 123 | 100 |
| 06 | 22,21 | 22,21 | 1,000 | 101,21 | 0,0 | 121 | 99 |
| 07 | 22,40 | 22,26 | 0,994 | 100,57 | -0,6 | 118 | 99 |
| 08 | 24,64 | 24,44 | 0,992 | 99,75 | -0,8 | 110 | 99 |
| 09 | 24,62 | 24,60 | 0,999 | 99,68 | -0,1 | 109 | 100 |
| 10 | 24,60 | 24,60 | 1,000 | 99,68 | 0,0 | 109 | 100 |
| 11 | 24,60 | 24,60 | 1,000 | 99,68 | 0,0 | 109 | 100 |
| 12 | 23,92 | 23,92 | 1,000 | 99,68 | 0,0 | 111 | 100 |

Time

#### Time Product dummy hedonic model

When using the time product dummy hedonic model each tariff package and each month is dummy coded. Similar to the matched model approach the comparison was made by the names of the tariff package, changes in the characteristics within the lifetime are not considered. The calculation was done for the entire period at once and 167 dummy coded variables for the tariff packages and 5 dummies for the time periods were introduced.

The index gives the same result as the matched model and the index with bridged overlap. The index does not react on the discontinuation of the Christmas tariffs in March. The difference between the Christmas packages and the new packages is all explained as quality difference between the two tariff packages.

The resulting model has a R² equal 0.9974 and an adj. R² = 0,9970. Table 23 shows the parameter estimates for the used time dummy variables. These time dummy parameters reflect the price development compared to last December. Most of them are not significantly different from zero, only in two months – May and June – the price development since last December can be rated as significant from zero (p < 0,05). This means that the prices measured with the help of the TPD-hedonic model shows almost no price changes for the entire period.

Table 23: Parameter estimates for the time dummy variables

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Month** | **β** | **Exp(β)** | **STDERR** | **T** | **PVALUE** |
| 01 | 0,00003 | 1,000 | 0,00482 | 0,01 | 0,9950 |
| 02 | 0,00218 | 1,002 | 0,00479 | 0,46 | 0,6487 |
| 03 | 0,00412 | 1,004 | 0,00484 | 0,85 | 0,3946 |
| 04 | 0,00161 | 1,002 | 0,00489 | 0,33 | 0,7412 |
| 05 | 0,00958 | 1,010 | 0,00491 | 1,95 | 0,0514 |
| 06 | 0,00960 | 1,010 | 0,00491 | 1,95 | 0,0509 |
| 07 | 0,00051 | 1,001 | 0,00496 | 0,10 | 0,9177 |
| 08 | 0,00046 | 1,000 | 0,00508 | 0,09 | 0,9282 |
| 09 | -0,00369 | 0,996 | 0,00513 | -0,72 | 0,4722 |
| 10 | -0,00369 | 0,996 | 0,00513 | -0,72 | 0,4722 |
| 11 | -0,00369 | 0,996 | 0,00513 | -0,72 | 0,4722 |
| 12 | -0,00557 | 0,994 | 0,00535 | -1,04 | 0,2985 |

#### Comparison of the implicit methods



Figure 1. Price development of implicit price indices for mobile phone tariffs from 12/2018 to 12/2019

Figure 1 shows the results of the average price index, the matched model index, the matched model index with bridged overlap and the time dummy product dummy hedonic model from December 2018 to December 2019. As can be easily seen the lines are almost parallel. This was expected and shows that the three methods are almost the same as they assign almost all price differences are rated as quality differences. If the included credits change then no explicit adjustment is made but the whole price change that occurs at the same time is used as estimate for the quality change at that time. These methods fail to correctly reflect price changes on the market, e.g. in March, when some Christmas sales packages ended and new ones with new names occurred on the market, the price change of the three methods is almost 0%, at the same time the average prices go up by 7%. It may be supposed that the implicit methods fail to reflect sales prices correctly for mobile phone packages. Moreover, it is supposed that the three methods will give an almost flat line also for a longer time period as it is typical in the mobile phone market that the prices of tariff package stay constant and new ones with different credits and names are introduced when prices are changing.

From April to May the prices increase a little bit more than in the other months. On the one hand true price increases are reflected in this change that comes from the change of the basic fee for three tariff packages but the remaining changes of four tariff packages also involve a change in the included characteristics. These are not adjusted for as the name of the package stays the same.

### Explicit Methods

The following section gives an overview of some explicit methods used for index compilation. Mainly hedonic variants are used for this section, namely the hedonic repricing method and the time dummy model in two variants – full period and adjacent periods.

#### Hedonic Model – Repricing Method

In the beginning a regression model with all metric variables and the logarithm of the basic fee was tested. This model leaded to explained variances below 60%. The inclusion of the dummy coded variables improved the fit significantly. Table 25 shows the parameter estimates and other statistics concerning the single steps of the GB. All GB steps are significantly different from zero and are linear connected with the included GB. The more GB included the higher the parameter estimate.

The first model is a regression model for all time periods with all available variables single in a regression. The GB included in the basic fee within AT and within EU, the minutes within the EU have R² above 50%. They are followed by the binding period which is an indicator for subsidized mobile phones included in the contract. Also the classification as network operator vs. virtual network provider has an explained variance above 30%. The age limit, VOICE over LTE and minutes within the EU have rather low explained variances.

Table 24: Explained variances for regression models with single dummy coded variables as independent variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **R²** | **R² adj** | **# dummies** | **sign** |
| Minutes EU | 0,0636 | 0,0591 | 6 | 3 |
| Voice over LTE | 0,2295 | 0,2287 | 1 | all |
| Age limit | 0,0058 | 0,0048 | 1 | all |
| Network operator | 0,2512 | 0,2505 | 1 | all |
| Binding period | 0,3802 | 0,3791 | 3 | all |
| Minutes within AT | 0,5328 | 0,5306 | 6 | 2 |
| GB in Austria | 0,5768 | 0,5740 | 7 | all |
| GB in EU | 0,6586 | 0,6557 | 10 | all |

The full regression with GB within Austria and within EU, binding period, kind of provider, age limit, Voice over LTE and minutes within Austria yield an R² equal 0.9015 (adj. 0.8995). The fit of the model can be regarded as quite good. Table 25 gives an overview of the parameter estimates per dummy coded variable.

Table 25: Regression model for the whole period used for hedonic repricing

| **Variable** | **DF** | **Parameter****estimate** | **Standard****error** | **t-Value** | **Pr > |t|** | **Variance****inflation** |
| --- | --- | --- | --- | --- | --- | --- |
| Intercept | 1 | 1.69220 | 0.04870 | 34.75 | <.0001 | 0 |
| dummy\_1GB | 1 | 0,15380 | 0,04570 | 3,37 | 0,0008 | 6,71759 |
| dummy\_5GB | 1 | 0,32106 | 0,05009 | 6,41 | <.0001 | 9,98018 |
| dummy\_8GB | 1 | 0,52785 | 0,05072 | 10,41 | <.0001 | 6,45336 |
| dummy\_10GB | 1 | 0,56794 | 0,04978 | 11,41 | <.0001 | 11,95943 |
| dummy\_20GB | 1 | 0,71111 | 0,05024 | 14,15 | <.0001 | 10,56931 |
| dummy\_25GB | 1 | 0,81701 | 0,05253 | 15,55 | <.0001 | 7,88892 |
| dummy\_30GB | 1 | 0,95715 | 0,05155 | 18,57 | <.0001 | 9,46648 |
| dummy\_40GB | 1 | 1,13788 | 0,05288 | 21,52 | <.0001 | 7,37886 |
| dummy\_unlGB | 1 | 1,35478 | 0,05624 | 24,09 | <.0001 | 3,88193 |
| dummy\_12M | 1 | 0,36720 | 0,04425 | 8,30 | <.0001 | 1,11933 |
| dummy\_24M | 1 | 0,43198 | 0,01496 | 28,88 | <.0001 | 1,71480 |
| dummy\_20GB\_EU | 1 | 0,10633 | 0,02995 | 3,55 | 0,0004 | 1,37626 |
| dummy\_25GB\_EU | 1 |  |  |  |  |  |
| dummy\_30GB\_EU | 1 | 0,16887 | 0,03388 | 4,99 | <.0001 | 1,52653 |
| dummy\_40GB\_EU | 1 | 0,46985 | 0,03641 | 12,9 | <.0001 | 1,95335 |
| dummy\_500Min | 1 | 0,15592 | 0,02662 | 5,86 | <.0001 | 3,12251 |
| dummy\_1000Min | 1 | 0,29009 | 0,02807 | 10,34 | <.0001 | 3,35997 |
| dummy\_2000Min | 1 | 0,48020 | 0,03544 | 13,55 | <.0001 | 2,05348 |
| dummy\_unlMin | 1 | 0,45007 | 0,02702 | 16,65 | <.0001 | 6,12618 |
| Network operator | 1 | 0,32927 | 0,01926 | 17,10 | <.0001 | 2,83451 |
| Age restriction | 1 | -0,34251 | 0,02283 | -15,00 | <.0001 | 2,09841 |
| VOLTE | 1 | -0,14690 | 0,01892 | -7,76 | <.0001 | 2,26334 |

The dependent variable is the natural logarithm of the basic fee. The parameter estimates for GB in Austria, GB in EU and minutes in Austria increase dependent on the included service units. If a tariff includes more minutes in Austria, then the parameter estimate is higher. The age limit indicates if a tariff can only be selected under a certain age. These are special offers to youth and students, therefore the coefficient is negative. The inclusion of the age dummy was necessary because there was an interaction with 25 GB included. Without the age limit dummy the parameter estimate for 25 GB was lower than the other ones and produced a break in the increasing parameter estimates. The reason for that is that youth and student tariffs often have 25 GB included and offered at a lower price than unconstrained tariff packages.

The network operators, these are the three big providers which run an own network which can be used by virtual network providers, offer tariff packages at a higher price than VNPs. The binding period, which has positive parameter estimates, is an indicator for including subsidized mobile phones in the contract. If one selects a tariff with binding a new subsidized mobile phone is offered at the same time and the monthly costs are higher. This effect is indicated by the binding period dummy.

This model was used for the calculation of a repricing model with a reduced data set. All tariff packages which were available for the whole time period were taken. Then the remaining tariff packages were listed and those selected which were available in December 2018. If a tariff package wasn’t offered any more than in the following month a tariff package was selected that was as similar as possible and assigned to the one of the previous month. For both tariff package the basic fee was estimated by the help of the above described hedonic model and the price of the previous month was adjusted with the factor between the two estimated prices. In the next step monthly indices were calculated and a chained version starting with 12/2018 = 100 was established.

Table 26: Index (2018/12 = 100) for the hedonic repricing model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **Month** | **Mean previous month** | **Mean current month** | **Monthly index** | **Index (2018/12 = 100)** |
| 2018 | 12 |  |  |  | 100,00 |
| 2019 | 1 | 21,50 | 21,50 | 100,00 | 100,00 |
| 2 | 21,49 | 21,60 | 100,55 | 100,55 |
| 3 | 21,39 | 22,06 | 103,12 | 103,69 |
| 4 | 22,12 | 21,53 | 97,32 | 100,91 |
| 5 | 21,91 | 21,99 | 100,36 | 101,27 |
| 6 | 21,99 | 21,99 | 100,00 | 101,27 |
| 7 | 22,00 | 21,84 | 99,24 | 100,50 |
| 8 | 22,05 | 21,92 | 99,40 | 99,90 |
| 9 | 22,12 | 22,06 | 99,75 | 99,65 |
| 10 | 22,06 | 22,06 | 100,00 | 99,65 |
| 11 | 22,06 | 22,06 | 100,00 | 99,65 |
| 12 | 22,69 | 21,81 | 96,13 | 95,79 |

The hedonic repricing index reacts on the increasing prices when the cheap Christmas tariff packages disappear from the market and new tariff packages appear which have almost the same services included in almost the same amount but the prices are rather higher. It is also able to deal with the situation of new tariff packages for various reasons, like in the case of month 5/2019 with the renaming of T-Mobile to Magenta and the upcoming of various new tariff packages. The introduction of the unlimited packages in 8/2019 does not lead to an increase in index values. All three events summarised seem to be reflected as it should be for the consumer price index.

#### Hedonic model – time dummy method

In the next step the model found for the hedonic repricing method in Section 6.5 was enlarged by time dummies. In one version the whole period was used in another the data of two adjacent time periods were used for calculation. These are the two popular options for index calculation. The adjacent time period method has some advantages in index production and should be the preferred one. Both variants have similar results, they show a significant increase in March followed by a decrease in the following month. As for the hedonic repricing model the discontinuation of the Christmas tariffs shows an increase, but the introduction of the unlimited tariff packages are not seen as full price increase in the index.

Table 27: Parameter estimates for adjacent time dummy hedonic method and for the entire period (full)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **full** | **M\_01** | **M\_02** | **M\_03** | **M\_04** | **M\_05** | **M\_06** | **M\_07** | **M\_08** | **M\_09** | **M\_10** | **M\_11** | **M\_12** |
| R² | 0.9019 | 0.8949 | 0.8908 | 0.8957 | 0.9131 | 0.9168 | 0.9256 | 0.9275 | 0.921 | 0.9164 | 0.9193 | 0.9189 | 0.8981 |
| RMSE | 0.2107 | 0.2162 | 0.2206 | 0.2184 | 0.1997 | 0.1994 | 0.1941 | 0.1952 | 0.2048 | 0.2073 | 0.2033 | 0.2039 | 0.2263 |
| Intercept | 1.6909 | 1.6897 | 1.6897 | 1.685 | 1.704 | 1.6888 | 1.6971 | 1.6923 | 1.6904 | 1.688 | 1.6922 | 1.6941 | 1.718 |
| 1 GB AT | 0.1522 | 0.1469 | 0.1499 | 0.1124 | 0.0682 | 0.0885 | 0.0769 | 0.0477 | 0.0884 | 0.2049 | 0.254 | 0.2544 | 0.2568 |
| 5 GB AT | 0.3237 | 0.2606 | 0.2541 | 0.2281 | 0.3045 | 0.3646 | 0.2696 | 0.2035 | 0.2717 | 0.3685 | 0.3655 | 0.3703 | 0.3742 |
| 8 GB AT | 0.5334 | 0.5676 | 0.5233 | 0.4644 | 0.5 | 0.5474 | 0.4606 | 0.3966 | 0.5004 | 0.5731 | 0.5422 | 0.5464 | 0.5755 |
| 10 GB AT | 0.5732 | 0.6014 | 0.6188 | 0.5634 | 0.5516 | 0.5815 | 0.4849 | 0.4154 | 0.5032 | 0.6056 | 0.5909 | 0.5958 | 0.6229 |
| 20 GB AT | 0.7304 | 0.6418 | 0.6472 | 0.6186 | 0.6724 | 0.7431 | 0.6716 | 0.5778 | 0.6419 | 0.7756 | 0.8055 | 0.8095 | 0.8149 |
| 25 GB AT | 0.7771 | 0.7136 | 0.742 | 0.7109 | 0.7612 | 0.8598 | 0.7507 | 0.6079 | 0.6673 | 0.7793 | 0.7928 | 0.796 | 0.7737 |
| 30 GB AT | 0.9722 | 0.8242 | 0.858 | 0.8679 | 0.9639 | 1.0368 | 0.9528 | 0.8734 | 0.9623 | 1.0758 | 1.0753 | 1.0779 | 0.9607 |
| 40 GB AT | 1.1348 | 0.9419 | 0.9527 | 1.0238 | 1.2048 | 1.2196 | 1.1058 | 0.9612 | 1.0664 | 1.2301 | 1.2253 | 1.2391 | 1.1808 |
| unl GB AT | 1.3439 | 1.5227 | 1.5227 | 1.5227 | 1.5227 | 1.4765 | 1.3916 | 1.3104 | 1.3069 | 1.3795 | 1.3854 | 1.3645 | 1.283 |
| 25 GB EU | 0.1834 | 0.4992 | 0.4737 | 0.2596 | 0.0681 | 0.0091 | 0.0311 | 0.1259 | 0.1425 | 0.1768 | 0.206 | 0.2072 | 0.2586 |
| 30 GB EU | 0.1648 | 0.4546 | 0.4193 | 0.2953 | 0.1496 | 0.1331 | 0.1364 | 0.1526 | 0.1294 | 0.0983 | 0.0827 | 0.092 | 0.2029 |
| 40 GB EU | 0.4718 | 0.6974 | 0.6841 | 0.5462 | 0.3874 | 0.4551 | 0.4909 | 0.529 | 0.4897 | 0.4395 | 0.4336 | 0.41 | 0.4932 |
| 500 Min | 0.1515 | 0.2246 | 0.2089 | 0.237 | 0.1745 | 0.1224 | 0.2097 | 0.2849 | 0.2341 | 0.1008 | 0.0734 | 0.0679 | 0.0829 |
| 1000 Min | 0.2844 | 0.3999 | 0.4137 | 0.4409 | 0.3552 | 0.2901 | 0.3738 | 0.4095 | 0.2903 | 0.1763 | 0.1947 | 0.1887 | 0.1601 |
| 2000 Min | 0.4690 | 0.6145 | 0.5903 | 0.5736 | 0.4438 | 0.4103 | 0.515 | 0.6184 | 0.5144 | 0.3554 | 0.36 | 0.3517 | 0.3883 |
| Unl. Min | 0.4429 | 0.4452 | 0.449 | 0.5052 | 0.4963 | 0.4128 | 0.5045 | 0.5942 | 0.5366 | 0.4423 | 0.4641 | 0.4616 | 0.4171 |
| 12 month | 0.3476 | 0.3024 | 0.2892 | 0.3661 | 0.4456 | 0.4451 | 0.4691 | 0.4404 | 0 |  |  |  |  |
| 24month | 0.4177 | 0.3508 | 0.356 | 0.3891 | 0.4294 | 0.4549 | 0.4422 | 0.4313 | 0.4088 | 0.4121 | 0.4166 | 0.4152 | 0.3933 |
| Network op | 0.3493 | 0.3057 | 0.3128 | 0.41 | 0.4752 | 0.3818 | 0.3616 | 0.3275 | 0.3383 | 0.3557 | 0.3488 | 0.3518 | 0.3448 |
| Age limit | -0.3478 | -0.2651 | -0.2761 | -0.3605 | -0.3942 | -0.3723 | -0.344 | -0.3007 | -0.2982 | -0.3219 | -0.3533 | -0.3527 | -0.3207 |
| VOLTE | -0,1386 | -0.0348 | -0.0397 | -0.1654 | -0.3043 | -0.2268 | -0.2127 | -0.1752 | -0.1741 | -0.1963 | -0.2043 | -0.209 | -0.1863 |
| td\_coeff | 0.4429 | 0.0049 | 0.0051 | 0.0143 | -0.0236 | 0.0069 | -0.0098 | -0.0002 | 0.0036 | 0.0083 | 0 | -0.0038 | -0.0516 |
| td\_faktor | 0.34927 | 1.0049 | 1.0051 | 1.0144 | 0.9766 | 1.0069 | 0.9903 | 0.9998 | 1.0036 | 1.0084 | 1 | 0.9962 | 0.9497 |
| Td coeff Full |  | 0.0059 | 0.0084 | 0.0269 | 0.0011 | 0.0082 | -0.0010 | -0.0057 | -0.0013 | 0.0091 | 0.0091 | 0.0053 | -0.0496 |
| TD factor full |  | 1.0060 | 1.0084 | 1.0273 | 1.0011 | 1.0082 | 0.9990 | 0.9943 | 0.9987 | 1.0092 | 1.0092 | 1.0053 | 0.9516 |

Table 28: Index (2018/12 = 100) and parameter estimates (PE) for the time dummies of the time dummy hedonic method for the full period and for adjacent periods

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Month** | **Full period** | **Adjacent time period** |
| **β** | **Exp (β)** | **Index** | **%** | **β** | **Exp (β)** | **Index** | **%** |
| 2018 | 12 |   |   | 100,00 |   |   |   | 100,00 |   |
| 2019 | 1 | 0,0059 | 1,0060 | 100,60 | 0,6 | 0,0049 | 1,0049 | 100,49 | 0,5 |
| 2 | 0,0084 | 1,0084 | 100,84 | 0,2 | 0,0051 | 1,0051 | 101,00 | 0,5 |
| 3 | 0,0269 | 1,0273 | 102,73 | 1,9 | 0,0143 | 1,0144 | 102,46 | 1,4 |
| 4 | 0,0011 | 1,0011 | 100,11 | -2,5 | -0,0236 | 0,9766 | 100,06 | -2,3 |
| 5 | 0,0082 | 1,0082 | 100,82 | 0,7 | 0,0069 | 1,0069 | 100,75 | 0,7 |
| 6 | -0,0010 | 0,9990 | 99,90 | -0,9 | -0,0098 | 0,9903 | 99,77 | -1,0 |
| 7 | -0,0057 | 0,9943 | 99,43 | -0,5 | -0,0002 | 0,9998 | 99,75 | 0,0 |
| 8 | -0,0013 | 0,9987 | 99,87 | 0,4 | 0,0036 | 1,0036 | 100,11 | 0,4 |
| 9 | 0,0091 | 1,0092 | 100,92 | 1,0 | 0,0083 | 1,0084 | 100,95 | 0,8 |
| 10 | 0,0091 | 1,0092 | 100,92 | 0,0 | 0 | 1 | 100,95 | 0,0 |
| 11 | 0,0053 | 1,0053 | 100,53 | -0,4 | -0,0038 | 0,9962 | 100,57 | -0,4 |
| 12 | -0,0496 | 0,9516 | 95,16 | -5,3 | -0,0516 | 0,9497 | 95,51 | -5,0 |

The two variants of the hedonic time dummy method evolve rather similar. Both react in March to the end of the Christmas tariffs and do not increase when the unlimited tariffs at the end of the period are introduced. From April to May there is the introduction of Magenta, which is a renaming of T-Mobile combined with a range of new tariffs. Together with the price increase there is an increase of included GB in AT and within EU which explains the price increase.

#### Comparison of explicit methods

Figure 2 shows the resulting indices from the two hedonic variants repricing and time dummy with the implicit time product dummy hedonic method and an index computed from average prices. It can be seen that the two explicit hedonic variants react to changes in prices e.g. for the reason of special sales packages and that the prices increase once the sales period ends. Also changes in tariff packages within their lifetime are adjusted for. Both do not show a price increase when the unlimited packages occur on the market. They show a slight price increase compared to no price change or a small decrease shown by the time product dummy hedonic method as reference for the implicit methods.



Figure 2: Comparison of different hedonic indices for mobile phone tariffs

## Results with weighting information

When validating the results from section 6 it became evident that the VNPs get a rather big impact compared to the network operators as they are more than the network operators (17 compared to 3) and some of them offer a rather large variety of different tariff packages – up to 25 for one VNP. Table 29 shows the number of packages per provider. It can be seen that the network operators have a total of around 30 packages and the VNPs have between 60 and 80 packages. When this prices are averaged without weights – neither outlet nor item weights – the influence of the VNPs is double as high as the ones of the network operators although it is known that the network operators have a bigger market share than the VNPs.

To evaluate the impact of the weights two variants of weighting schemes were used to calculate weighted hedonic time dummy indices. The already presented hedonic time dummy result has an equal weight for all packages no matter where they come from. A first variant introduced equal weighted providers. This means that first the 100% of the weight is divided by the number of providers and then within each provider the corresponding share is divided by the number of packages within the provider. E.g. one package of NP 3 has a higher weight than one package of NP1 as the latter one has a wider variety of packages.

A second variant introduced true outlet weights, where the fact that the three network operators dominate the market is reflected in the weighting scheme and the multiplicity of service providers and their contracts get a lower weight. This means that one tariff package of the network providers has more influence / weight than one package of the service only providers. First the market shares for the network operators were assigned and then these shares were divided by the number of packages of the network operator. For VNPs the remaining weight, in the example in Table 30 this is 10%, was divided by the number of VNPs – assumed that they all have almost the same market share, and then the resulting number was divided by the number of packages within the VNPs. If one VNP offers a great variety of packages one single package has less influence as if one VNP has only a low number of packages.

Table 29: Number of tariff packages per network providers (NP) and service only providers (SOP)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **operator** | **12** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| NP 1 | 14 | 14 | 18 | 18 | 18 | 18 | 18 | 18 | 20 | 20 | 20 | 20 | 20 |
| NP 2 | 11 | 11 | 11 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| NP 3 | 6 | 6 | 6 | 6 | 6 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| ***Sum NP*** | ***31*** | ***31*** | ***35*** | ***37*** | ***37*** | ***43*** | ***43*** | ***43*** | ***45*** | ***45*** | ***45*** | ***45*** | ***45*** |
| SOP 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SOP 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 |
| SOP 3 | 1 | 1 |  | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SOP 4 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| SOP 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SOP 6 |  |  | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| SOP 7 | 3 | 3 |  |  |  |  |  |  |  |  |  |  |  |
| SOP 8 | 8 | 8 | 8 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| SOP 9 | 6 | 6 | 6 | 6 | 6 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| SOP 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SOP 11 | 29 | 27 | 30 | 26 | 26 | 27 | 29 | 28 | 18 | 16 | 16 | 16 | 17 |
| SOP 12 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| SOP 13 | 8 | 9 | 9 | 8 | 8 | 9 | 9 | 7 | 7 | 7 | 7 | 7 | 7 |
| SOP 14 | 4 | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |
| SOP 15 | 5 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| SOP 16 |  |  |  |  | 1 | 1 |  |  |  |  |  |  |  |
| SOP 17 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ***Sum SOP*** | ***83*** | ***83*** | ***86*** | ***84*** | ***83*** | ***80*** | ***79*** | ***76*** | ***66*** | ***64*** | ***64*** | ***64*** | ***66*** |
| **Total** | **114** | **114** | **121** | **121** | **120** | **123** | **122** | **119** | **111** | **109** | **109** | **109** | **111** |

Table 30: Example for different weights options used for weighted hedonic time dummy regressions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Provider** | **Package** | **Equal weight per package** | **Equal weight per provider** | **Weighted by est. Market shares** |
| **Provider** | **package** | **provider** | **Package** |
| NO 1 | A | 12,5 | 25 | 25 | 50 | 50 |
| NO 2 | B | 12,5 | 25 | 12,5 | 40 | 20 |
|  | C | 12,5 | 12,5 | 20 |
| VNP 1 | D | 12,5 | 25 | 12,5 | 10 | 2,5 |
|  | E | 12,5 | 12,5 | 2,5 |
| VNP 2 | F | 12,5 | 25 | 8,3 | 1,7 |
|  | G | 12,5 | 8,3 | 1,7 |
|  | H | 12,5 | 8,3 | 1,7 |

The result of the two versions can be found in Table 31. The parameter estimates for the dummy variables for included GB within Austria are almost the same between the equal weighted, the market weighted and the version without weights (each package has the same weight). There is a difference for the small 1GB category which is higher in the market weighted version compared to the equal weighted version and the one without weighting. In the former it is also not significant. Also an inspection of the confidence intervals of the parameter estimates shows that the estimate falls out of the reciprocal confidence interval of the other weighted model. Over time this category with a low amount of GB included is decreasing over time. In December 2018 12,3% of the tariff packages had around 1GB included, in November there are only 8,3% of tariff packages with 1 GB.

For GB within the EU there are fewer dummy variables as the included GB within the EU are lower than the ones included for usage in Austria. The same effect can be observed. The first category – the 25GB dummy – parameter estimate is higher in the market weighted model than in the two others.

Table 31: Parameter estimates (β) and corresponding statistics of equal and market weighted time dummy hedonic models

|  |  |  |
| --- | --- | --- |
| **Dummy** | **Equal weighted time dummy model** | **Market weighted time dummy model** |
| **β** | **STDERR** | **T** | **P-value** | **β** | **STDERR** | **T** | **P-value** |
| Intercept | 1,71484 | 0,05997 | 28,60 | 0,0000 | 1,68601 | 0,19864 | 8,49 | 0,0000 |
| 1 GB | 0,10900 | 0,06200 | 1,76 | 0,0789 | 0,50605 | 0,20034 | 2,53 | 0,0117 |
| 5 GB | 0,46045 | 0,06304 | 7,30 | 0,0000 | 0,47203 | 0,20268 | 2,33 | 0,0200 |
| 8 GB | 0,59594 | 0,06027 | 9,89 | 0,0000 | 0,78490 | 0,20154 | 3,89 | 0,0001 |
| 10 GB | 0,70670 | 0,06233 | 11,34 | 0,0000 | 0,65767 | 0,20150 | 3,26 | 0,0011 |
| 20 GB | 0,81419 | 0,06238 | 13,05 | 0,0000 | 0,91366 | 0,20124 | 4,54 | 0,0000 |
| 25 GB | 0,91189 | 0,06225 | 14,65 | 0,0000 | 1,03120 | 0,20156 | 5,12 | 0,0000 |
| 30 GB | 1,08950 | 0,06397 | 17,03 | 0,0000 | 1,15916 | 0,20146 | 5,75 | 0,0000 |
| 40 GB | 1,24215 | 0,06689 | 18,57 | 0,0000 | 1,20023 | 0,20223 | 5,93 | 0,0000 |
| unlimited GB | 1,47842 | 0,06092 | 24,27 | 0,0000 | 1,41076 | 0,20224 | 6,98 | 0,0000 |
| 25 GB\_EU | 0,14439 | 0,03744 | 3,86 | 0,0001 | 0,41127 | 0,03104 | 13,25 | 0,0000 |
| 30 GB\_EU | 0,17260 | 0,03842 | 4,49 | 0,0000 | 0,21861 | 0,02775 | 7,88 | 0,0000 |
| 40 GB\_EU | 0,45712 | 0,04312 | 10,60 | 0,0000 | 0,61348 | 0,03255 | 18,84 | 0,0000 |
| 12 month | 0,21956 | 0,04272 | 5,14 | 0,0000 | 0,40895 | 0,04996 | 8,19 | 0,0000 |
| 24 month | 0,38825 | 0,01568 | 24,76 | 0,0000 | 0,43998 | 0,01327 | 33,16 | 0,0000 |
| 500 Min | 0,03035 | 0,02795 | 1,09 | 0,2777 | -0,01510 | 0,03823 | -0,40 | 0,6929 |
| 1000 Min | 0,14636 | 0,02306 | 6,35 | 0,0000 | 0,03808 | 0,04621 | 0,82 | 0,4100 |
| 2000 Min | 0,46184 | 0,03001 | 15,39 | 0,0000 | 0,20726 | 0,04154 | 4,99 | 0,0000 |
| unlimited Min | 0,33050 | 0,02202 | 15,01 | 0,0000 | 0,22562 | 0,03403 | 6,63 | 0,0000 |
| Network operator | 0,31530 | 0,02197 | 14,35 | 0,0000 | 0,32200 | 0,02460 | 13,09 | 0,0000 |
| Age limit | -0,37014 | 0,02560 | -14,46 | 0,0000 | -0,40930 | 0,01586 | -25,80 | 0,0000 |
| td\_01 | -0,10307 | 0,02083 | -4,95 | 0,0000 | -0,12830 | 0,01675 | -7,66 | 0,0000 |
| td\_02 | 0,00162 | 0,02511 | 0,06 | 0,9486 | 0,00013 | 0,02514 | 0,01 | 0,9957 |
| td\_03 | 0,01782 | 0,02513 | 0,71 | 0,4785 | 0,01375 | 0,02520 | 0,55 | 0,5856 |
| td\_04 | 0,01591 | 0,02516 | 0,63 | 0,5273 | 0,06967 | 0,02558 | 2,72 | 0,0065 |
| td\_05 | 0,01737 | 0,02520 | 0,69 | 0,4907 | 0,02373 | 0,02581 | 0,92 | 0,3581 |
| td\_06 | 0,02515 | 0,02521 | 1,00 | 0,3186 | 0,05235 | 0,02622 | 2,00 | 0,0461 |
| td\_07 | 0,00040 | 0,02521 | 0,02 | 0,9874 | 0,05096 | 0,02623 | 1,94 | 0,0522 |
| td\_08 | -0,00324 | 0,02526 | -0,13 | 0,8980 | 0,04952 | 0,02629 | 1,88 | 0,0599 |
| td\_09 | -0,00478 | 0,02527 | -0,19 | 0,8500 | 0,04205 | 0,02641 | 1,59 | 0,1116 |
| td\_10 | 0,00667 | 0,02530 | 0,26 | 0,7922 | 0,04568 | 0,02641 | 1,73 | 0,0840 |
| td\_11 | 0,00667 | 0,02530 | 0,26 | 0,7922 | 0,04568 | 0,02641 | 1,73 | 0,0840 |
| td\_12 | 0,00476 | 0,02530 | 0,19 | 0,8507 | 0,03395 | 0,02640 | 1,29 | 0,1988 |

Summarised it can be said, that the full model (tariff packages equal weighted) and the equal weighted model are behaving similar; the market weighted model gives a somewhat different result. This result can be found for almost all parameter estimates of the different dummy coded variables and time dummies. The index for the equal weighted hedonics and hedonics without weights is lower than the index with equal weights for providers. Figure 3 shows the results of the unweighted version against the two weighted versions. The two indexes without weights and with provider equal weights give lower results than the one with market weights. This is due to the fact that the Christmas package was from one of the network operators which have a higher weight in the market weights than in the two other variants. This issue has a lower effect on the other two indices. Then the introduction of new tariff packages from one network operator together with a rebranding in May has a bigger effect on the market weighted index.



Figure 3: Weighted hedonic price indices for mobile phone tariffs from 12/2018 to 12/2019

## Summary

Different methods were used to deal with price measurement for telecommunication. Average prices of tariff packages per month have the main drawback that they neither adjust for quality nor for quantity differences. Therefore, they react on price changes which are not pure price changes but stipulated by the inclusion of a greater service range. As different service parts are included in the same basic fee of a tariff package there is no possibility to correct for those differences over time within the computation of averages prices.

Secondly some implicit methods were compiled, a matched model approach, one with bridged overlap and a time product dummy hedonic model. All three give almost the same results – more or less a flat line – and all three methods fail at capturing the fast evolving telecommunication market developments as the nature of tariff packages is to stay unchanged during their lifetime. If the characteristics bundle is changing, then a new tariff package with a new name is introduced. The price change between the old and the new tariff package is not taken into account but singled out of the index. These indices do not reflect special offered packages neither when they are introduced on the market as price decrease nor when they leave the market as price increases. They also do not change due to the introduction of packages with more included volume but they assign the whole price difference as quality difference and show no other price development than 0%. If the price changes due to indexation during lifetime, then this event is shown in the index.

Then some variants of hedonics – these are variants of explicit methods - were compiled. A hedonic repricing model with included minutes, GB and other package components as independent variable and the logarithm of the price as dependent variable was the starting point. Furthermore, time dummies for each month were added and the index development conducted from the corresponding parameter estimates. In terms of resources the time dummy method is less intensive as no one-to-one adjustments have to be made and the whole variety of packages each month can be used.

From validation of the above results it became clear that the results are heavily affected by the Virtual Network Providers (VNPs) which offer a lot more different tariff package compared to the network operators although the network operators have higher market shares than the VNPs. Therefore, different options of weights were introduced – equal weighted provider weights and market share weighted provider weights. Both variants showed better results which are closer to the official estimated price developments than the unweighted cases.

## Conclusion

To get the data in a usable format for the computation of price indices is a rather resource intensive task but compared to other goods it was less complicated. Main difficulties arise from the pool credit for included services (service usage is defined jointly). There seems to be no optimal solution but as only the included minutes are in the resulting method this problem has a minor influence on the results.

A regression analysis with linear variables for the basic fee and included services (both metric) gave only a low fit of the regression (not reported here). Therefore, all metric variables were dummy coded into steps of the included service and the logarithm of the basic fee was taken. The basic fee turned out to be not normal distributed, but the logarithm of the basic fee is. The notion ‘quality’ used for the included services is used although it is not strictly quality but also quantity that is adjusted for. It is comparable to hedonic regression for owner occupied flats where the m² are used as an independent variable which is not strictly connected with quality but also quantity (the bigger the more expensive).

The application of bridged overlap adds nothing to the matched model. The choice of the bridge is known to be sensitive but there are not many options for the bridge. As most of the price changes go along with the introduction of new tariff packages there is no price change observable for the bridge.

The hedonic analysis shows that the included GB within AT and within the EU, the included minutes, the length of the binding of the contract – that is the presence of a subsidized phone, the choice of a network operator and special tariffs for students and VOICO over LTE are significant variables for the quality of a tariff package.

Table 32: Overview of methods and properties in certain situations

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **AP** | **MM** | **MM BO** | **TDPD** | **Repricing** | **HTD** |
| Reaction to unlimited packages | Up | No | No | No | No |  |
| New providers/ renaming |  | X | X | X | X |  |
| New contents/ same name |  | X | X | X | Yes | Yes |
| End of sales tariffs | Yes | X | X | X | yes | Yes |
| Start of sales tariffs |  |  |  |  | yes | Yes |
| Corrects for included service between packages | No | Yes | Yes | Yes | yes | Yes |
| Corrects for included service within packages | No | No | No | No | Yes | Yes |
| Uses all data | Yes | No | No | NO | Yes | Yes |

\* AP = average prices; MM = matched model, MM BO = Matched Model with bridged overlap, TDPD = time dummy product dummy hedonic model, Repricing = repricing hedonic model, HTD = time dummy hedonic model

Table 32 shows the different methods and rates their reaction to different situations that occur on the telecommunication market. The best properties have the two explicit methods that is the hedonic repricing method and the hedonic time dummy method. The implicit methods show almost flat lines and react neither to the upcoming of sales tariff packages nor to the end. As changes in the definition of tariff packages go along with a renaming of the tariff package almost all price changes are rated as quality changes. The two explicit methods hedonic repricing and hedonic time dummy method react to different changes on the market – renaming of packages, start and end of sales prices, changes of characteristics within the lifetime of a tariff package – in an adequate way. Therefore, there is a clear preference for the usage of these methods.

Concerning the usage of weights there should be an investigation in more detail. One current drawback is the missing information about market shares. This information was published up to 2018 by the national regulatory body but was stopped for some valid reasons. Nevertheless, currently there is no alternative for the measurement of the market shares, especially as the reported turnovers include business consumption which, if used without correction, overestimates the share of the network providers for the private consumers.

For the weighting of tariff packages for one network provider the history of weights for tariff packages is available. As soon as there is a longer time series from the web scraped data these weighting information could be used to improve the calculation of price indices for the telecommunication market.

For the Austrian HICP it is intended to change to one variant of the two explicit hedonic models and it is assumed that this could improve the calculation of price indices for telecommunication in a significant way. Furthermore, it should be extended to the prepaid market – once the computation of a monthly ‘price’ is settled. Here the effective costs computed by the internet platform could be helpful.

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