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Conference Paper

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24th Biennial Conference of the International Telecommunications Society (ITS): "New bottles for new wine: digital transformation demands new policies and strategies", Seoul, Korea, 23-26 June, 2024

Provided in Cooperation with:
International Telecommunications Society (ITS)

Hedonic Broadband Prices Amid High Inflation and Market Consolidation: A Hungarian Case Study

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Paper to be presented at the 24th Biennial Conference of the ITS, 2024

Abstract

This study examines the changes in consumer prices within the fixed broadband market in Hungary between 2020 and 2023, a period marked by unprecedented, government-backed market consolidation. Leveraging a hedonic price regression methodology, we inspect price changes in the context of internet service provider (ISP) differences, inflation, and various service features offered in broadband plans. The hedonic method allows for quality-adjusted price tracking over time, in addition to offering insights into the intrinsic value placed on various plan characteristics by consumers. We demonstrate that the hedonic methodology holds significant value for regulators and market players in developing effective price monitoring systems. Our analysis reveals that following the market consolidation, the previously stagnant price level increased, and the pricing strategies of the three major service providers underwent notable transformations. The two providers involved in the consolidation significantly raised their prices, with Vodafone becoming the most expensive provider in the country and Digi nearly losing its price advantage. By the end of the period, the third player, Telekom, offered more favourable hedonic prices compared to 2020. The cumulative increase in the average hedonic price index over the examined period was almost 20%, remaining significantly below the change in the consumer price index. The estimated intrinsic prices of the various fixed broadband plan characteristics are consistent with previous literature. The study underlines the utility of the hedonic methodology in providing nuanced insights into ISP pricing behaviour and fixed retail telecom market dynamics. The study opens up potential areas for future research, such as extending the analysis to television and voice telephony and monitoring future trends in light of the recent changes in market structure.

Keywords: hedonic regression, telecommunications, fixed broadband, pricing, Hungary

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1 Introduction

Fixed broadband markets are constantly developing. The capabilities and features of fixed broadband services improve continually. At the same time, market structure may change drastically due to mergers and acquisitions. In many countries inflationary pressures have also increased significantly in recent years. Simply comparing the price levels of commercial broadband plans over time cannot reflect all the concurrent changes in the broadband market. We therefore apply the hedonic approach to identify quality-adjusted price changes, as well as the pricing behaviour of the various service providers.

In this paper, we aim to analyse price changes in the fixed broadband market in Hungary, between 2020 and 2023, a time of great upheaval. There are a few reasons why Hungary's broadband market is of interest. The Hungarian fixed broadband market is very advanced in comparison to other EU countries in many respects, despite belonging to the group of less developed, lower GDP per capita EU countries overall. High-speed broadband coverage and household penetration are high, while PPP-adjusted broadband prices, as analysed by the EU in 2021, were very low in comparison. Prices have also historically differed strongly by service provider, with the more established incumbents being challenged by a dynamic competitor. The market structure, however, underwent a major change in the years investigated. In a mere year and a half, the Hungarian fixed retail telecommunications markets ended up with just two major competitors, with the only important challenger being swallowed up in the process. In addition, the consolidation was unchallenged, and in fact, government-backed and partly state-financed, with a complete lack of competition screening. While the effects of such major changes may take years to really show, it is worth investigating whether the acquired challenger's prices have begun to adjust.

Based on the circumstances detailed above, we investigate three main research questions using the hedonic price regressions. We look at how hedonic prices have developed over the past three years, as well as how various internet service providers (ISPs) differ from each other in their pricing. We are also interested in comparing the overall hedonic price changes with other measures: tracing how inflation changed pricing behaviour overall and specifically for each ISP, comparing broadband hedonic price changes with the Consumer Price Index, as well as with the telecommunications price indices calculated by the Hungarian Central Statistical Office (KSH). Finally, we also discuss the relative values of the various service characteristics of the broadband plans.

In addition to addressing these research questions, we present the hedonic regression methodology as a potential price monitoring tool for regulators and market players. We suggest utilizing raw price data publicly disclosed by ISPs, which allows for a timelier analysis compared to regulators retrospectively collecting data from ISPs' regular submissions. This price monitoring tool is especially valuable during periods of significant market upheaval, as it enables the differentiation of price changes resulting in price inflation from those attributable to the continuously improving quality parameters of services offered. We are interested in analysing this market from the consumer's point of view: the demand-side hedonic price changes given supply-side pricing. Therefore, it is important to implement some manner of weighting; ISPs' market shares can be very out of sync with the number of possible broadband plans they offer.

We have created the database used ourselves, spanning the retail fixed telecommunications markets, including broadband, television and voice telephony, for the three largest ISPs which are nationwide competitors. Together, these three ISPs have an over 80% market share nationally on the fixed broadband market. The analysis presented in this paper focuses on a subsample of the plans in the database, the ones that contain broadband. Despite this, we take into account several variables which pertain to TV and voice telephony, since consumers often choose plans that contain multiple services. We cover all possible options a consumer has when selecting a fixed telecom plan that includes broadband internet. To capture the effects of various non-broadband plan characteristics, we create tailored variables to deal with certain typical features of these plans, such as TV packages with various numbers of channels, or voice telephony packages with a certain number of free on- or off-net minutes. We also create a multifaceted weighting system to best account for the consumers' overall demand patterns based on the public information we have available: we weight according to ISP market shares, the share of fixed broadband, TV and voice telephony combinations, and also test various assumptions on the ratio of consumers who purchase supplementary options for their plans. The database contains over 100 thousand possible subscription plans including broadband for the four years analysed.

Our main results are the following. In mid-2020, at the beginning of the period under investigation, the two larger competitors were pricing very similarly to each other, while the challenger, Digi, was pricing significantly lower. Following the process of consolidation during which Digi was acquired, Digi's hedonic price index increased by nearly 50% between 2022 and 2023, eroding the majority of its affordability advantage. The merger's other participant, Vodafone, increased its prices by over 10% during the examined period, becoming the most expensive ISP in hedonic terms. Second, we see that the average hedonic price change over the period investigated is much lower than overall inflation, as measured by CPI.

The structure of the paper is the following. Section 2 introduces the relevant literature for applying the hedonic approach to telecommunications markets and specifically, fixed broadband pricing. Section 3 describes the Hungarian fixed broadband market in European comparison, as discusses the development of the market structure between 2020 and 2023. Section 4 presents our methodology, data and the modelling considerations. Section 5 details our results, and Section 6 discusses the results and concludes.

2 Literature review

Telecommunication services have several features and are usually sold in bundles. These features change over time, especially the characteristics and quality of broadband internet access and mobile services. A meaningful evaluation and comparison of the prices of broadband plans must therefore control for quality differences. One possibility is to match offers with given quality attributes, but this is too rigid an approach. The alternative, hedonic comparison is more flexible in comparing the price levels and price changes of technology goods and services.

Kelvin Lancaster (1971) and Rosen (1974) were principal contributors to laying the theoretical foundations of hedonic comparisons, although empirical hedonic studies had in fact been conducted earlier (see Court, 1939, Stone, 1956 and Griliches, 1961), using the dummy variable method for estimating hedonic price indices. Griliches was the first to use an approach other than the dummy variable method in his econometric studies of the used car market (see Griliches, 1961 and Ohta and Griliches, 1976).

The use of a hedonic analysis for the telecommunications sector has an almost two-decade long history. There are two different lines of hedonic research in the field of telecommunications, one focusing on devices, the other on services. The basic methodology is similar but not more so than to any other field where the hedonic approach is used. We therefore focus on the hedonic analysis of the services only. The pioneers in this subfield were the studies by Varoutas *et al.* (2008) on leased lines, Greenstein and McDevitt (2011) on the US fixed broadband market, Wallsten and Riso (2014) on OECD international broadband prices, and Karamti and Grzybowski (2010) on the French mobile market.

When summarising the methodological issues raised and approaches used in the literature, we focus on the papers tackling fixed broadband. In addition to those we discuss some of the studies on mobile services as well, since these can also provide useful insights into how hedonic regression can be best applied to fixed telecom services, as they face very similar issues and complexity in the modelling and estimations.

We identify three different main goals of the hedonic analyses of the telecom fixed broadband services. The first is to measure some type of quality-adjusted price change over time, essentially the evolution of a price index, often in order to create a more informative index than the matching-based ones usually applied by statistical offices. Such analyses also typically evaluate the change over time in the value of various specific service characteristics, such as the Mbps price of download speed (see, for example, Greenstein and McDevitt, 2011, Lyons and Savage, 2013, Calzada and Martinez-Santos, 2014, OFCOM, 2018). Second, some studies focus on international price comparisons, using the hedonic method to implement a type of price benchmarking, such as the seminal study prepared for the OECD by Corrado and Ukhaneva (2016); but see also the papers of Calzada and Martinez-Santos (2014), Wallsten and Riso (2014), FCC (2018 and 2022) and Aravantinos *et al.* (2022). Third, the goal of price comparison can be to evaluate the effects of a certain policy, a change in market structure, or a change in the competitive environment (see Correa and Crocioni 2012, Lyons and Savage, 2013, Diaz-Pinés and Fanfalone, 2015; Centre for International Economics, 2015 and 2016, Lyons and Coyne, 2017 on fixed broadband, Nicolle *et al.*, 2018, and OFCOM, 2018 on mobile markets). The primary focus of this paper is to achieve the first goal, as well as to identify any possible preliminary effects of the recent changes in market structure in Hungary – the third type of goal.

Studies also differ from each other in the source of their data. Some rely on regularly updated databases by entities such as Teligen (Corrado and Ukhaneva, 2016), Point Topic (Greenstein and McDevitt, 2011, Wallsten and Riso, 2014), Tarifica (Munoz-Acevedo and Grzybowski, 2023) or regulators' price comparison sites (Lyons and Savage, 2013, Lyons and Coyne, 2017), while others collect data themselves. While collecting and collating data can be very time consuming, it has the advantage that the database can be tailored more exactly to the researchers' needs and objectives. However, this strategy is viable mostly in single country studies (see OFCOM, 2018, Pápai et al. 2024), or limited time frame and geographic scope international comparisons (see for example Dippon and Helleloid, 2023). This paper is based on a database we compiled ourselves.

The dependent variable is some form of price measure, while the control variables are the features of the various plans. These can be numeric or categoric, often in the form of indicators (dummies). Despite broadband services often being sold in bundles, and even if these plans are included in the data, there is often a lack of sufficiently detailed information on the characteristics of the bundled television and/or voice telephony services (see, for example, Calzada and Martinez-Santos, 2014, Corrado and Ukhaneva, 2016, Lyons and Savage, 2013, Lyons and Coyne, 2017, Aravantinos *et al.*, 2022). If the researchers have the information, coding these characteristics requires exploration and creativity (see Wallsten and Riso, 2014 or Diaz-Pinés and Fanfalone, 2015, Dippon and Helleloid, 2023). Another problematic area is data availability on and handling of the often complex and numerous supplementary services. There are no fixed standards or best practices on the best way to compile the database, and this is therefore an area where the researcher can be creative in finding the best solutions for the given place, time and scope. We discuss our database in detail in Section 4.

Hedonic studies differ greatly in the length of the time period covered, as well as the frequency of the data. Studies can be done for just one point in time (such as Correa and Crocioni, 2012, Diaz-Pinés and Fanfalone, 2015, Centre for International Economics, 2015 and 2016, Dippon and Helleloid, 2023), or for periods spanning several years, as most of the papers do. The frequency can be anywhere between annual and monthly. In this paper, we are looking at annual data for 2020 – 2023, leaving open the possibility for the time scope to be extended in the future.

When several time periods are used in the estimation, there are two main approaches for taking advantage of this. The first is to estimate a pooled cross-section with a time period dummy. This approach is more common (see, for example, Calzada and Martinez-Santos, 2014, Wallsten and Riso, 2014, Lyons and Coyne, 2017, Aravantinos *et al.*, 2022), although in its pure form it assumes that the pricing of features does not change over time, which can be less realistic, especially over several years. With pooled cross sections it is an option to use interactions between certain features and the time dummies to address this issue (see Corrado and Ukhaneva, 2016). An alternative approach, especially for longer time spans, recommended by the hedonic methodology literature (see Triplett, 2004, de Haan and Diewert, 2013) is to use chains of pooled cross sections of adjacent periods, with a time dummy (see the studies by Karamti and Grzybowski, 2010 on the French or Pápai *et al.*, 2024 on the Hungarian mobile market). This approach is less restrictive on the coefficients of the various characteristics. In this paper, we use pooled cross sections for adjacent periods with time dummies.

Economic theory does not give any general guidance on what form of function should be used, but for index calculation, the logarithmic form may be preferable (Triplett, 2004, Corrado and Ukhaneva, 2016). In the literature, the dependent variable, price, is often used in logarithmic form (see, for example, Greenstein and McDevitt, 2011, Lyons and Savage, 2013, Calzada and Martinez-Santos, 2014, Corrado and Ukhaneva, 2016, Lyons and Coyne, 2017, Aravantinos *et al.*, 2022), but it also can be in level form (Wallsten and Riso, 2014, Centre for International Economics, 2015 and 2016, Nicolle *et al.,* 2018). The decision can be based on fit, on tests, or the desired type of index. Based on various considerations discussed in Section 4, this paper uses the dependent price variable in logarithmic form. Service characteristics are either categorical or numerical; while download and upload speed usually appear in logarithmic form (see, for example, Greenstein and McDevitt, 2011, Calzada and Martinez-Santos, 2014, Diaz-Pinés and Fanfalone, 2015, Corrado and Ukhaneva, 2016, Lyons and Coyne, 2017). The estimation is typically run using ordinary least squares, but sometimes more sophisticated techniques are applied: weighted least squares, two-stage least squares, or even random coefficient models (see Corrado and Ukhaneva, 2016, Dippon and Helleloid, 2023). Time dummies serve as fixed effects, as do country or region indicators (when relevant) and operator indicators.

A common issue in these hedonic studies is the question of weighting. The demand for different plans is not evenly distributed, some plans are more popular than others. Further, different operators and operators in different countries have vastly differing approaches to how plans are constructed: some may offer more streamlined plans with low variety others play with many more options available. In the end, the number of plans resulting from the possible combinations of the features by operator may differ significantly. In this situation some form of weighting may therefore be desirable, based on markets shares or more sophisticated demand side information. However, most researchers have no access to weighting data and weights are not used in most of the studies, because of the lack of this information. When studies do use weighting, it is most often the ISP market share (see Centre for International Economics, 2015 and 2016, Lyons and Coyne, 2017, Nicolle *et al.,* 2018, Pápai *et al.*, 2024). In this paper, we use a complex weighting system, explained in detail in Section 4.

3 The Hungarian fixed broadband market

The Hungarian fixed broadband market is very advanced in comparison to other EU countries in many respects, despite belonging to the group of less developed EU countries overall. In this section, we will first show some comparative data on the key indicators, such as high-speed coverage, penetration and price, then discuss the possible reasons behind these indicators being so favourable. We then discuss the recent, major changes in market structure which could disrupt the previous trends. These indictors and market developments form the backdrop to our analysis.

3.1 Key performance indicators on the Hungarian fixed broadband market

In 2022, Hungary was in 22th position in the EU27 based on PPP-adjusted GDP per capita with around 76% of the EU27 average. In terms of high-speed broadband deployment and development however, Hungary is among the leaders within the EU. Table 1 below shows some of the key fixed broadband market indicators for Hungary and the EU27 average.[4]

[4] The source of the key indicators presented here is https://digital-decade-desi.digital-strategy.ec.europa.eu/.

Table 1: Key performance indicators on the Hungarian fixed broadband market, 2023

Indicator	EU27	Hungary
Very High-Speed Network (VHCN) coverage (speed ≥ 100Mbps)	73.4%	80.3%
FTTP coverage	56.5%	70.1%
At least 100 Mbps fixed broadband take-up	55.1%	69.8%
At least 1 Gbps fixed broadband take-up	13.8%	29.8%

Source: Digital Decade DESI Data

Hungary is well above the EU27 average both in terms of coverage and take-up of newer generation broadband networks. With over 80% Very High Capacity Networks (VHCN) coverage, Hungary ranks 11th, but in terms of actual take-up, it ranks even higher, at 6th place. The difference compared to the EU27 average is almost 15 percentage points. The indicators in which Hungary truly excels are related to fiber coverage and Gigabit take-up. While its 70.1% Fiber to the Premises (FTTP) coverage places Hungary only 14th in the EU, in terms of take-up of speeds at least 1 Gbps, the ratio is almost double the EU27 average, with Hungary ranking second, preceded only by France.

The differences compared to the EU27 average and Hungary's position in the rankings demonstrate not only that Hungary has an advanced high-speed broadband infrastructure, but in the actual take-up than in coverage suggests that the demand side is even more receptive to the adoption of higher speed services. On the other hand, the competitive pressure presented by Digi has driven providers towards offering gigabit speeds for relatively affordable prices. These factors combine to create an optimal environment for a modern, high-functioning, and competitive broadband market. In addition to the above key indicators, it is also worth showing broadband *prices* in international comparison. Price comparison is a complex endeavour, as demonstrated in this paper. However, the European Commission makes an annual calculation for pre-defined single and bundled broadband packages (see Empirica, 2024. Broadband is stratified by speed (the highest benchmarked category being a download speed of at least 200 Mbps). In this calculation, which is PPP-adjusted, Hungary was the country with the third cheapest single broadband connection in the highest, based on the same fibre optic plan sold by Digi offering 1000 Mbps download speed at less than 18 EUR a month (PPP). While bundled packages fare slightly worse, Hungary is still in the top half of the ranking.

Overall, Hungarian users in general were able to achieve a decent broadband speed at a good price. Both these outcomes are the result of lively infrastructure competition between service providers competing with their own networks, as well as technologies. Regarding technology, the 17% share of legacy copper-based xDSL in Hungary was much lower than the 45.7% EU27 average in 2021. Cable had the largest share in technologies (46%), however FTTP's share was also higher than xDSL's and has been increasing. Access-based service competition has never been a factor and is now practically nil.

Regarding competitors, there were 3 strong infrastructure-based competitors on the national level in 2021, which were present in most cities. Two parallel networks are normal in many locations, and three is not unusual in the largest cities. To make the picture a little messier, these main competitors operate networks with different technologies in different cities. The incumbency position is not simple either, because these national players were incumbents in some locations and challengers in others.

A further source of the advantage in broadband price is that Hungary applies a reduced 5% VAT rate to internet services, making broadband cheaper by policy. The opposite is true for telecom services, with the "normal" 27% VAT applying to voice and TV services. In addition to the VAT rate, an extra handicap exists on the phone service, a 2 HUF tax on voice and SMS services (per minute or item), which has driven the relative price of telephony even higher compared to the internet. These positive and negative distortions compared to the mainstream, homogeneous taxing policy in the EU certainly affect the benchmarking results.

3.2 Significant structural changes on the Hungarian fixed broadband markets

A significant number of changes have occurred on the Hungarian telecommunications markets over the past few years, in the form of consolidation and integration, as well as an increased state and government-backed presence. These have impacted both retail and wholesale fixed markets and partially the mobile markets. Scrutinizing the effects of these changes in a structured manner forms one of the motivations behind this research: it is worth first documenting and later analysing how the changes in market structure are reflected in pricing behaviour. In this section, we discuss the main developments on the fixed retail markets for broadband, the focus of this paper, but also alluding to voice and TV, mobile and wholesale when appropriate.

Up until 2018, there were 4 major competitors on the Hungarian fixed retail markets: Magyar Telekom, UPC, Digi and Invitel, and several smaller, local operators. Of these, at this time, only Magyar Telekom (hereafter: Telekom), a subsidiary of Deutsche Telekom, was fully integrated, both vertically and horizontally, being present on wholesale markets as well as retail fixed markets in broadband, TV and voice, and the retail mobile market.

The first round of consolidation began in 2018, when Digi, a highly competitive, innovative market player acquired Invitel, the struggling former incumbent of many Hungarian regions. This merger was deeply scrutinised by the Hungarian Competition Authority, and finally passed with significant remedies: in many locations, Invitel's retail business was divested to its twin company, Invitech (that previously supplied Invitel's wholesale services). In 2019, a large step was taken towards integration on the Hungarian markets, when Vodafone, one of three Hungarian MNOs, acquired UPC as part of a larger, European merger deal.[5] The Hungarian part of this merger was cleared without commitments by the Commission.

While these mergers impacted all telecommunications markets, they did not effectively end up changing the number of overall number of players on the national fixed retail market, and were analysed in detail by competition agencies. Starting in 2021, however, a larger upheaval began when a small IT company with government ties, 4iG, began a series of acquisitions which eluded competition overview, due to the Hungarian government deeming them of "national strategic importance". First, in September 2021, 4iG acquired Invitech, which included the divestments from the Digi/Invitel merger; a relatively minor acquisition in view

[5] The merger was investigated by the European Commission, see decision M.8864.

of what was to come. Second, just two months later. 4iG acquired Digi, the third largest, highly innovative, maverick-type competitor on the Hungarian retail fixed markets.[6,7] Finally, to top it off, in August 2022, 4iG and the Hungarian state announced that they were to jointly acquire the entire Hungarian business of Vodafone, with 4iG having the controlling number of shares. By January 2023, this merger had also gone through. In a mere year and a half, therefore, Hungarian fixed retail markets went from having 4 major competitors to just two: 4iG and Telekom. The speed and scope of this unchallenged, in fact, government-backed process of consolidation, with a completely lack of competition screening, is unprecedented, and its effects on competition on the market could be significant.

4 Data and methodology

4.1 Research questions

This study currently focuses on how broadband prices changed over the past four years, between 2020 and 2023. Within this fairly broad topic, there are some issues we are especially interested in. First, due to the recent, unprecedented process of concentration on the Hungarian fixed telecommunications markets discussed in Section 3, we look at how various ISPs differ from each other in their pricing, as well as how this has developed over the past three years. The market players' background and strategy differ significantly: Telekom as a former voice telephony incumbent still maintains a legacy copper network in many locations while actively substituting it with fibre. It also has a significant cable footprint in many cities. UPC (acquired by Vodafone, which is now owned by 4iG) mainly relies on its extensive cable infrastructure. Digi (now also owned by 4iG) was an aggressive, maverick entrant, with a modern fibre network, and highly competitive pricing.

Second, we are also interested in comparing the overall hedonic price changes with other measures: tracing how inflation changed pricing behaviour overall and specifically for each ISP, comparing broadband hedonic price changes with the Consumer Price Index, as well as with the telecommunications price indices calculated by the Hungarian Central Statistical Office (KSH). Third, we also discuss the changing value of various service characteristics of the broadband plans, and how these compare to the results found in other studies.

Third, we explore the potential of hedonic regression methodology as a tool for price monitoring by regulators and industry stakeholders. By leveraging publicly available raw price data from ISPs, this method offers a possibly quicker and more efficient alternative to conventional price monitoring tools. To do this, we thoroughly explain the data collection process and the methodological considerations, thus emphasizing the necessary steps needed to reproduce such an analysis.

4.2 The hedonic regression

[6] In this way, the original, complete version of the Digi/Invitel merger became a reality. Since the merger was deemed of "national strategic importance", however, it was not investigated by any competition agency.

[7] It is worth mentioning that in February 2022, 4iG also acquired Antenna Hungária. While Antenna Hungária was not a very significant firm (active in the TV and wholesale markets), it was at this point state-owned, and itself had a 25% stake in one of the three MNOs in Hungary, Yettel (then called Telenor) and its mobile infrastructure firm Cetin.

A hedonic function assumes that the price of a differentiated product or service is the function of the quantitative or qualitative measures of its key characteristics. For the correct model specification, it is important to include all relevant product or service characteristics in the equation, in order to avoid the omitted variable bias. For our purposes, we use the so-called time dummy variable model, which is one of the established hedonic methods (see Triplett, 2004). In this model the price is regressed on the relevant service characteristics, and a separate dummy variable is included in the model to capture the time effect. This time dummy coefficient is in itself a variable of interest in this study.

Together with our main variables of interest the time and service provider dummy variables, the coefficients of the relevant product characteristics are also estimated. The other estimated coefficients can be considered the implicit prices of the service characteristics. These coefficients are informative in themselves, but in a time dummy hedonic model we are first and foremost using them as controls, in order to get a good estimate of the time coefficient, which measures the quality-adjusted price change over the given period.

Though the parameters can simply be estimated using ordinary least squares (OLS), we use weighted least squares (WLS) for reasons discussed in detail in Section 4.5.

The time dummy hedonic regression can be estimated on a pooled data set, but if there is a high likelihood that the role and effects of the individual characteristics change significantly over the observed period, it is well established in the literature that it is best to perform estimations for adjacent, pooled pairs of time periods (see Triplett, 2004 or de Haan and Diewert, 2013). The time flexibility of the estimated implicit prices can be further enhanced by introducing interaction terms between the time dummy and the variables recording certain characteristics. This approach is especially useful when aiming for the calculation of yearly values of provider-specific hedonic price indices.

4.3 Data

4.3.1 Data collection

The dataset collected and collated for this study includes data on the prices, service characteristics and features of publicly available residential fixed telecom subscription plans, encompassing broadband, television, and voice telephony services, which were provided by the three main Hungarian ISPs (Telekom, Vodafone, Digi) between 2020 and 2023. These three providers served over 80% percent of the Hungarian broadband, voice telephony and television consumers in the studied period, and their overall share has been growing over the past five years (see NMHH, 2023). All of these providers are also present on the mobile telecom market, although Digi was a subscale new entrant there with moderate spectrum endowment, coverage and speed and a very low market share.

We collected the data manually from the publicly available General Terms and Conditions documents[8] of these three ISPs, downloaded from their websites.

[8] The General Contract Terms and Conditions must be published and kept up to date by the ISPs by law. These documents contain all the current terms and conditions related to the services and plans offered by the ISPs. Although the structure of the documents differs among providers, they all include information on quality and price for the currently available single and bundled subscription plans. It is important to note that these

The dataset contains information on both the basic and optional supplementary packages that were available to new subscribers at the end of the first half (practically, June) of each year during the period under study. Throughout the study period, all three ISPs offered separate and bundled plans for fixed broadband, television, and voice telephony services, as well as various supplementary options for their television plans, such as extra channels, recording options, and on-demand movie libraries. Additionally, two of the providers, Telekom and Vodafone, offered optional packages for their voice plans that included extra minutes in various directions.

We collected information on three main groups of service characteristics:

- prices and attributes of available single play base plans,
- bundles of TV and voice services with broadband plans, as well as the prices, attributes, and compatibility of optional supplementary packages,
- overall discount options applicable to different plans (discounts associated with bundling, loyalty contracts and electronic billing)

Utilizing this information, we constructed records for all available plans a new consumer could select:

- single-service base plans,
- single-service plans with additional options,
- multi-service (multiplay) base plans, and
- multi-service (multiplay) plans with added options.

Collating the data was a multi-step process. We started with the data on the basic single play plans and any possible supplementary options, then we generated every possible combination of a base plan and one or more supplementary options based on the availability restrictions outlined in the terms and conditions documents.

In addition to single play plans, the providers also offer bundled double and triple play plans, which combine two or three types of services, including broadband, television, and voice telephony. Data from the National Media and Communications Authority (NMHH) suggests that the fixed telecommunications market is dominated by these multiplay packages, as most Hungarian consumers subscribe to service bundles.[9] To promote these bundled plans, providers offer discounts for certain multiplay packages, making them a more affordable and lucrative alternative to purchasing the services separately.

Multiplay discounts are only available for bundles that include specific plans. If consumers wish to combine other plans, they can do so without a discount, which is equivalent to buying multiple single play plans separately. However, if they opt for discounted bundles, the overall price of the services is lower, which incentivizes consumers to buy services in a bundle. We generated every possible combination of the different service plans, including basic plans

documents contain the listed offers of the providers, which are generally available but may differ from the personalized or time-limited discount offers available occasionally on the providers' websites or targeted directly at special customer groups.

[9] Based on data published in NMHH (2023), over 71% of the users of fixed telecom services chose bundled multiplay services in 2023. In 2020, this ratio was around 64%.

and those with supplementary options, and when relevant, applied the corresponding bundling discounts to these plans.

Beyond bundle discounts and optional packages, ISPs provide two main types of discounts, which can be applied to the price of certain plans, subject to the general terms and conditions.

One such discount is the loyalty discount, from which consumers can benefit if they sign a loyalty contract with the provider for a designated period. A crucial feature of these contracts is that if the service is terminated before the end of the contract, the discount granted under the agreement must be reimbursed. The structure of these discounts can vary from one ISP and package to another. Sometimes the discount is applicable to the monthly fee for the entire period, other times the provider waives the monthly fee for the initial few months. In our database these discounts have been standardized by simply dividing the total monthly fee payable over the duration of the loyalty contract by the number of months in that period. Thus, if the discount was offered by the ISP for only some months of the period, we distributed it over the monthly fees for the entire period.

In Hungary, the maximum "normal" loyalty period is 12 months. For a longer period, ISPs can only establish a loyalty contract if they offer discounts on electronic equipment they sell (mobile phones, internet technology devices, television sets, etc.). Since only discounts with a 12-month loyalty contract are relevant for the price of broadband services, we have only considered these in our study. The other discount that can be applied, in the form of a fixed reduction of the monthly fee, and irrespective of the subscription type, is the discount for receiving and paying bills online.

For consumers, opting for these discounts is not as self-evident as for bundled packages. Here, in exchange for the discount, the consumer makes a concession, i.e., they commit to a service provider or forego receiving physical copies of their bills. Therefore, for some consumers, it might be a rational choice to abstain from these discounts. Consequently, we have included in our database the packages both with and without these discounts.

By combining basic plans with supplementary options, creating discounted bundles, and applying the generally available discounts, we identified over 104 thousand possible subscription plans from which a new customer could choose. Each plan represents an observation in the dataset. Table 2 shows the number of observations (possible plans) grouped by year, provider and the type of the plan.

Table 2: The number of observations in final dataset, by year, provider and plan type

Year	Provider	Single play base plans	Multiplay base plans	Multiplay plans with options
2020	Telekom	23	748	12416
	Vodafone	26	792	10086
	Digi	9	93	150
2021	Telekom	26	1452	18882
	Vodafone	34	986	11527
	Digi	9	93	150
2022	Telekom	24	1875	26136
	Vodafone	27	484	6326
	Digi	9	81	126
2023	Telekom	24	1875	22626
	Vodafone	26	564	6246
	Digi	22	174	268

As the table shows, the number of possible plans varies significantly by year and provider. This discrepancy can be attributed to the diverse strategies adopted by different ISPs in specific years, influencing how consumers can combine various services.

4.3.3 Variables and coding

In constructing our database, the key challenge involved accurately capturing plan attributes from terms and conditions documents and deciding which variables to include and how to appropriately code them.

The variables in the dataset record the price of each plan and the relevant service features and characteristics that could have an impact on the prices. To accommodate all plans in a single dataset, we included all relevant price and feature variables for all three types of services. The following groups of variables were recorded:

- *Basic identifiers:* date, provider, type of plan (basic or with supplementary options, single or bundled, and if bundled, which services are included), and name of the plan.
- *Overall contract related characteristics:* loyalty period and e-discount provided for using electronic invoices and payments.
- *Features of the fixed telephone service:* whether on-net and or off-net fixed and/or mobile calls are unlimited in some way or paid by minute, price per minute of calls to fixed and mobile networks, number of included minutes.
- *Features of the television service:* number of SD and HD channels, HBO option, on-demand movie library option, and recording option.
- *Features of the fixed broadband service:* physical medium of the service (DSL, Cable or Fiber), advertised maximum download and upload speeds, and also the guaranteed minimum download and upload speeds.
- *Prices* of included telephone, television and broadband services, and total price of plan with discounts applied.

For certain variables, coding is straightforward – for instance, it's reasonable to suggest that the plan's price should be coded as a continuous numeric variable, or that the provider, the plan type, and the internet service medium should be recorded as categorical variables.

Certain variables' coding involved decisions aimed at balancing the need for precise representation of the actual characteristic and ensuring maximum usability within our model to address the research questions. Opting to treat maximum and minimum download/upload speeds as continuous variables, despite their clustering around standard speeds, enabled the accurate tracking of associated price changes. In line with the common practice in the literature, we anticipated the need for logarithmic transformation during estimation, to account for the proportionally smaller price increase linked to higher speeds.

The challenge of coding TV service channels, a key differentiator, emerged from the issue of SD and HD versions, which often broadcast the same content, but impact user experience. Plans including both versions seem more valuable than those with only SD. However, quantifying this added value is complex. For simplicity, we treated both HD and SD versions as one channel if they were in the same package. This led to a channel number index variable, where we combined the counts of HD and SD channels, and an HD channel without an SD counterpart was counted twice.

Another significant consideration is recording the minutes included in the voice service in the database. ISPs offer bundled minutes in several plans, often unlimited. However, they frequently limit the networks within which these minutes can be used for calls to their own (fixed or both fixed and mobile) networks. However, taking into account the different sizes of the internalized network externality can be important. This is particularly relevant for unlimited calling packages, since the size of an ISP's customer base determines the actual value that unlimited calling represents to the consumer. It can be reasonably argued, for example, that in the case of Telekom, which serves more than two-thirds of the fixed voice and around 45% of the mobile market, unlimited calls within its own network represent a much higher value than in the case of Digi, which has a significantly smaller subscriber base (both fixed and mobile). We have addressed this problem by creating a variable that specifies the percentage of the number of Hungarian subscriptions (including residential and business) that can be reached by the actual unlimited or limited offer. As some packages also offer unlimited calls to mobile networks, we have included both fixed and mobile numbers in the calculation. This way, we have effectively converted a fundamentally categorical variable into a continuous one and accommodated the effect of network externalities for phone packages.

4.4 Methodology

There are a number of methodological choices and assumptions we had to make in the course of the analysis. We detail these here.

An important first issue is that of functional form. The dependent variable, price, is given in Hungarian forints, but a common transformation in hedonic analysis is to use the logarithmic form of the dependent variable. An advantage of the logarithmic form is that it can make the interpretation of coefficients somewhat simpler, as they can be interpreted as percentages. In general, a logarithmic transformation may also be beneficial in bringing the distribution of the variable closer to a normal Bell-curve when needed. A commonly used statistical test for determining the optimal functional form of the estimation is the Box-Cox test. In our case, the λ-parameter of the test is between -0.38 and -0.02 which suggests that the optimal variance stabilizing transformation is achieved by using the natural logarithmic transformation of the dependent variable.

A second choice is to handle single play and multiplay (bundled) plans together. This provides the opportunity to make a more sophisticated comparison and is also used in recent hedonic studies (see Wallsten and Riso 2014, Diaz-Pinés and Fanfalone 2015, Corrado and Ukhaneva 2016). We compiled our database to contain information on all available fixed retail plans (broadband, TV and voice), and all their characteristics. With such a database, we have the ability to control for all the relevant characteristics of each bundle, and there is no need to separate single and multiplay plans. Incidentally, we can, at a later date, also investigate the hedonic price progression of TV and voice plans in a similar way to broadband plans.

Finally, we use pooled cross sections for adjacent periods with time dummies. Therefore, we are only assuming that service characteristics' values remain the same for two consecutive time periods (years), not for all three. We therefore estimated our main model specification on pairs of adjacent years, which was possible as we had a large enough number of observations for each year. In the case of the provider-specific price differences, we aimed for the possibility of an even more detailed analysis, thus, within regressions estimated on adjacent years we included the interaction between our time and provider variables. This way we allowed for any non-linear change in time of the provider-specific price differences. We also estimated the pooled model of all three years as a robustness check, however.

The equation in general form is the following:

$$p_i^{j,t} = \alpha + \sum_k \beta_k * z_{i,k}^{j,t} + \gamma^j * c^j + \delta^t * d^t + \theta^{j,t} * c^j * d^t + \varepsilon_i^{j,t},$$

where:

- $p_i^{j,t}$ is the price of plan *i* (*i = 0, …, M)* offered by provider *j* (*j = 0, …, N)* in period *t* (*t = 0, …, T);*
- α is the intercept;
- $z_{i,k}^{j,t}$ is the value of characteristic *k* (*k = 1, …, K)* of product *i* offered by provider *j* in period *t*;
- β_k is the parameter (implicit price) of characteristic *k*;

c^j is the dummy variable for provider *j*;

γ^j is the parameter of the provider dummy (provider fixed effect);

d^t is the dummy variable for period *t*;

δ^t is the parameter of the period dummy (the overall yearly change in prices);

$\theta^{j,t}$ is the parameter of the provider-year interaction term (the provider-specific yearly deviation);

$\varepsilon_i^{j,t}$ is the random variation in the price of plan *i* offered by provider *j* in period *t*.

We are mainly interested in the change in the general price level and the price difference between providers and their annual change. As seen above, the service provider variable is treated as a category variable in the analysis. The statistical programs, including R, automatically convert these into several dummy variables. In order to avoid the dummy variable trap, one of the dummies, called the base level, is left out from among the variables. In this case, if a provider is defined as the base level, the intercept will be the price level of this provider, and the base price level of the other providers will be the sum of this value and the estimated coefficient for that provider. However, in our case, we are also interested in the average price level and its changes. We therefore depart from the classical dummy coding and use a more appropriate alternative, where the average price is the "base price level" and the deviation of the price level of the operators could be defined in relation to it. If we apply so-called effect coding to the service provider dummy variable, then the intercept will be the national average and the coefficients of providers give the deviation from it. This also has the advantage that no matter which dummy is omitted from the model, the intercept remains the same.

Effect coding was developed by Sweeney and Ulveling (Sweeny and Ulveling, 1972). While dummy coding gives value 1 to the indicated category level and 0 to the others, effect coding assigns a value of -1 (and not 0) to the omitted category, and the others are coded the same way as with dummy coding. This allows both the mean level and the level of specific service provider categories to be estimated directly.[10] With effect coding and OLS estimation, the intercept is the grand mean. Since we use WLS for the estimation, the intercept in our results is the weighted mean national price level. We have used this effect coding method for the service provider variables.

4.5 Weighting

As seen above in Table 2, the offers of the three ISPs differ significantly in terms of the number of basic single play plans, supplementary options, and combinations of services in discounted bundles. Therefore, when trying to measure the changes in consumer prices, conducting an analysis without assigning weights to observations could lead to biased conclusions. With equal observation weights, ISPs with more segmented offers (i.e., a higher number of observations per ISP) would be overrepresented in the estimation (simply due to having more records in the database). This also applies in relation to the basic and supplementary services

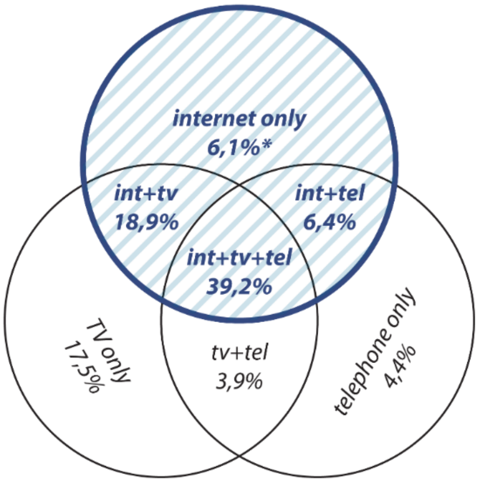
[10] For an introduction to effect coding, see also Grotenhuis et al. (2016), Daly et al. (2016), and Nieuwenhuis et al. (2017).

as well as single and multiplay plans. By assigning weights to certain observations, we can obtain a more accurate and realistic estimate of the hedonic price effects of certain characteristics, as perceived by potential new customers of these services.

When calculating the weights, we must base our assumptions on the available data on the underlying distribution of consumers among different types of plans. Ideally, the most accurate weights for every observation would be the number of customers currently using the plan. If this data is available – for example in the case of a regulator conducting such analysis – it should be used for weighting the observations, in order most accurately represent the importance of each plan. However, since in our case there was no publicly available data at this degree of disaggregation, we had to use the number of customers of wider categories of services and make some assumptions about the customers' distribution within those categories.

First, we have two relevant parameters concerning the customers' distribution that were publicly available: their choice between the three ISPs for the three types of fixed telecom services (represented by the ISPs' national "market shares" among internet, telephone, and television users) and their distribution between the different bundling constructions of services. The values of these parameters are provided by NMHH in their regularly published Fixed Telecom Market Report (see NMHH, 2022). The regulatory authority uses a coding system to represent the different categories of bundled services, which are grouped into seven categories, represented by Figure 1. As mentioned before, in this study we focus on the bundles including broadband service.

Figure 1: The different categories of bundled services and their shares in 2023



*Ratio = number of consumers of plan type / number of all consumers.
Source: NMMH Fixed Telecom Market Report, 2023. II. semester

We used the information from these two parameters in all versions of weighting that we considered. Using the number of fixed internet, telephone, and television users, as well as the ISPs' market shares for all three services, we first calculated the number of users of each service choosing a particular ISP. At this point, lacking other qualifying information, we assumed that the distribution of customers buying a service separately and in different bundle constructions does not differ among providers. This might be a strong assumption, but given the lack of less aggregated data, it is the most reasonable to assume. Assuming that the overall distribution of users applies to each provider-service type group, we calculated the number of users in each group who bought a certain service in different bundles. For example, the group of internet users with a Telekom subscription was divided into groups of single play, double play (bundled with TV or voice) and triple pay customers based on the overall number of customers in these groups. We could do this for all three services, meaning that bundled plans had different numbers of consumers, depending on the service from which the calculation started. This way, we calculated the number of consumers of each service, choosing a certain provider and buying the service in a certain type of bundling construction. Since in this study, our main interest is broadband, we concentrate on the internet users only.

Secondly, to calculate a weight to associate with each single observation (each possible plan) in each group, we had to divide the users in each group among the different plans. We had no specific information on the popularity of certain plans or certain options, so we calculated three versions and chose the one we deemed most plausible.

The approach used for the main results was the following. Since there are significantly more plans with supplementary options than plans with only base services, we didn't want to overestimate the role of supplementary options. For this reason, we divided the customers within a group into two subgroups: one subgroup buying plans with only base single or bundled services, and the other buying plans with supplementary options. We believe that such an equal division would be a good approximation of the consumer's true distribution resulting from their heterogeneous choices. Then, *within* each subgroup, we assigned each combination equal weights.

To check for robustness, we also calculated two simpler versions of weighting, albeit ones which we consider less plausible. Firstly, a very simplified approach is to ignore all observations with supplementary packages altogether. However, one of the significant contributions of this study is exactly the inclusion of these supplementary packages, as they provide additional information. Secondly, another simplified approach is to determine weights by evenly distributing the consumers in a given group among all the possible packages (i.e., observations) in that group. However, since there are significantly more plans with supplementary options than plans with only base services, this method could overemphasise the role of supplementary options.

5 Results

Based on the criteria outlined above, we selected the model which most effectively estimates our intended variables. In the final model, the price of the plan is used in logarithmic form. The model is estimated separately for pairs of years, thereby allowing the parameters to change in time. The explanatory variables used in the model are the year, the service provider, the logarithm of maximum download speed, the loyalty discount, the e-bill discount, the logarithm of TV channel number index, the presence of telephony in the bundle, the share of unlimited phone numbers, the share of phone numbers included in the 100-minute package, the presence of TV option packages (HBO packages, recording, video content), the medium of internet service, and the TV service technology. In the case of the provider-specific price differences, in order to allow for an even higher level of time flexibility, we use the interaction between the provider and the time dummy as an explanatory variable. For solid inference, standard errors are clustered by ISP. We used weighting to balance the estimation in the baseline model with weights calculated based on plan type and provider and balanced between base and optional plans. The goodness of fit for the final model is considered high for both year pairs (the R^2 is equal or higher than 0.88 for all adjacent periods). No serious multicollinearity emerged in the final model.[11] The results of the final model are shown in Table 3.

The regression results are reported according to the conventions, with one important modification, which is highly beneficial from a usability point of view. To avoid the "dummy variable trap" mentioned earlier, one level of the provider category variable must always be omitted from the data, so that we can only estimate the coefficients of the other two providers at a time. However, using the effect coding method, the omission of a provider variable does not affect the estimate of the intercept and the coefficients of the other variables. If we omit another provider dummy from the model and adjust the so-called effect contrast accordingly, we can use the same model to estimate the coefficients of the previously omitted provider, while the coefficients of the other variables in this alternative model will be the same, including the intercept. In the regression table below, we report the results of the model estimation when Telekom was the omitted category and we also report the coefficients of Telekom in italic, which is obtained by estimating the same model by including the dummy of Telekom and omitting another provider from the data.

[11] The largest value of the Generalized Variance Inflation Factors (GVIF) was 4.04, in the 2021-22 regression for the internet medium variable. It understandably correlates with the download speed. All other GVIF values were below 4. (For the description of GVIF, see Fox and Monette, 1992.)

Table 3: Estimation results of the hedonic regressions

	Dependent variable: Ln (Total Price)		
	20-21	**21-22**	**22-23**
Intercept	8.109 ***	8.137 ***	8.170 ***
	(0.072)	(0.073)	(0.048)
Telekom	*0.187 ****	*0.217 ****	*0.162 ****
	(0.013)	*(0.019)*	*(0.027)*
Digi	-0.428 ***	-0.395 ***	-0.407 ***
	(0.012)	(0.016)	(0.028)
Vodafone	0.241 ***	0.178 ***	0.245 ***
	(0.011)	(0.018)	(0.019)
2021	-0.019 ***		
	(0.002)		
Telekom 2021	*0.025 ****		
	(0.005)		
Digi 2021	0.043 ***		
	(0.002)		
Vodafone 2021	-0.068 ***		
	(0.003)		
2022		0.006	
		(0.006)	
Telekom 2022		*-0.091 ****	
		(0.008)	
Digi 2022		0.011	
		(0.020)	
Vodafone 2022		0.080 **	
		(0.027)	
2023			0.163 ***
			(0.006)
Telekom 2023			*-0.176 ****
			(0.010)
Digi 2023			0.268 ***
			(0.016)
Vodafone 2023			-0.092 ***
			(0.015)
Ln (Max Download Speed)	0.106 ***	0.096 ***	0.088 ***
	(0.013)	(0.013)	(0.009)
Copper	0.252 ***	0.186 ***	0.207 ***
	(0.036)	(0.046)	(0.051)
Fiber	-0.017 ***	-0.007	-0.003
	(0.005)	(0.008)	(0.006)
Loyalty discount	-0.092 *	-0.079	-0.083
	(0.036)	(0.049)	(0.054)
E-discount	-0.067 ***	-0.064 ***	-0.062 ***
	(0.003)	(0.003)	(0.004)
Telephone	0.121 ***	0.123 ***	0.132 ***
	(0.005)	(0.006)	(0.019)
Ln (Available number% unlimited)	0.036 ***	0.035 ***	0.032 ***
	(0.005)	(0.004)	(0.002)
Ln (Available number% 100 min)	0.047 ***	0.041 **	0.022 ***
	(0.012)	(0.016)	(0.002)
Ln (TV channel index)	0.081 ***	0.084 ***	0.095 ***
	(0.003)	(0.004)	(0.005)
SAT TV	-0.053 ***	-0.011	
	(0.004)	(0.013)	
HBO	0.255 ***	0.231 ***	0.206 ***
	(0.028)	(0.035)	(0.028)
HBO Max	0.259 ***	0.269 ***	0.279 ***
	(0.008)	(0.014)	(0.014)
Videotheque	0.100 ***	0.084 ***	0.066 **
	(0.011)	(0.018)	(0.022)
Video recording	0.089 ***	0.082 ***	0.101 **
	(0.010)	(0.018)	(0.033)
Mobile included	-0.122 ***	-0.125 ***	-0.189 **
	(0.001)	(0.002)	(0.059)
Number of Observations	45222	52618	49761
Adjusted R2	0.88	0.88	0.88
AIC	1243	1951	8486
F-statistic	16704	19556	18364

Clustered standard errors in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

5.1 Provider price levels and yearly change

In this study, our primary variables of interest are the yearly change in hedonic prices and the provider-specific differences and their evolution over time. While the introduction of the provider-year interaction term is useful for measuring time-variant provider-specific price differences, it also makes the calculation of the effects and interpretation of the results a little more challenging. Therefore, we calculate average and provider-specific hedonic price indices to accurately report the measured changes. In these indices, we consider the average hedonic price level in 2020 (the intercept of the first regression) as the baseline. All other values are calculated relative to this baseline by aggregating the parameters of the time and provider dummies and their interactions.

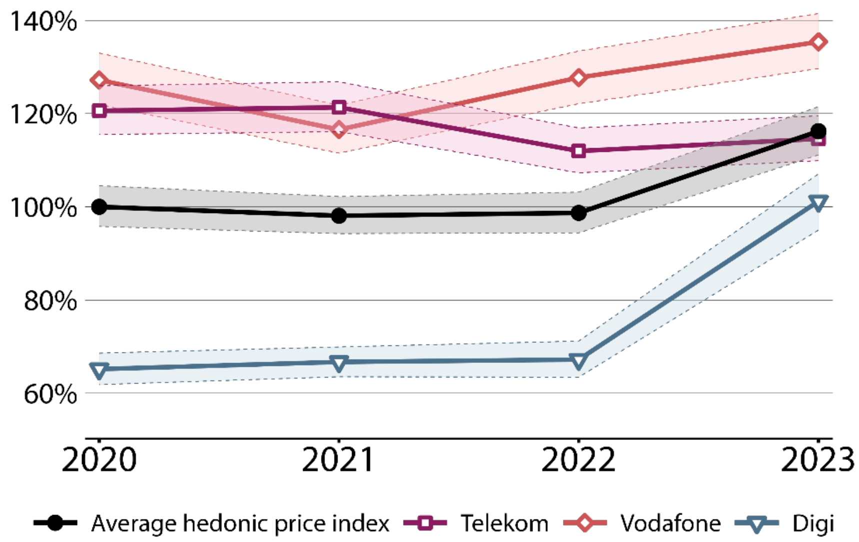
For the aggregate and cumulative values of the interacted year and service provider indicator variables of interest, we cannot obtain confidence intervals from the model, therefore we estimate them by using the bootstrap method.[12] From the resulting distribution of estimation results, which approximates normality, we determine, according to the percentile method, the lower and upper bounds within which the of bootstrap estimates are located, according to the chosen 95% confidence level.

Estimates in the loglinear model can be approximately interpreted as percentages for small changes. For larger changes, however, this approximation is imperfect, giving the lower estimate of the effect. Exact results of a unit change can be calculated by using the parameter value as an exponent of e. The same estimate of the dummy variable is biased (though still consistent). For a less biased estimate of a dummy variable when the dependent variable is in log form, a correction is needed (Kennedy, 1981). As Kennedy suggests we apply the Kennedy correction, using $x - Var(x) \, / \, 2$ instead of x in the exponent. Therefore, for the percentage change, the corrected estimate is $100(e^{x-Var(x)/2} - 1)$. Since the year and provider variables are dummies, by using the correct transformation this also implies that the corresponding hedonic price levels and changes can also be interpreted as percentages. However, if the variance of the estimate is small, compared to the size of estimate, the percentage result practically would be the same as without the correction.

For estimating the service provider percentage price differences and their changes we aggregate the corresponding year and provider interactions and use the bootstrap estimate of the variance of these aggregates for the correction. The results are summarized in Figure 2. The average and the provider-specific hedonic price indices are represented by the dots and lines of different colors.

[12] For a detailed description and discussion of the bootstrap method, see Efron és Tibshirani (1994).

Figure 2: The evolution of the estimated hedonic price index (2020 average = 100%)



As the graph shows, between 2020 and 2022, the average hedonic price index remained stable, but by 2023, it increased by nearly 17%, driven by price hikes from Digi and Vodafone. Telekom's prices were about 20% higher than the 2020-2021 average, dropped significantly in 2022, and then rose by 2 percentage points in 2023. However, due to the overall increase in the average price index, Telekom's prices ended below the average by 2023, marking a general decrease over the period.

Vodafone's prices started above the average, with a 28% markup similar to Telekom's. By 2021, Vodafone's prices dropped by 8 percentage points, aligning closely with Telekom's but still above the average. Significant price increases in 2022 and 2023 made Vodafone the most expensive operator by a statistically significant margin.

Digi maintained a highly competitive pricing strategy, with prices about 35% below average in 2020. This level persisted until 2022, but in 2023, Digi's prices surged by 46%, nearly matching Telekom's prices, yet still remaining the lowest among the operators.

Overall, the hedonic price index reveals distinct pricing trends for each operator. Initially, Telekom and Vodafone were above average and similar, while Digi was significantly below average. By 2023, Vodafone emerged as the most expensive, significantly above average, with Digi still the lowest-priced but much closer to Telekom's level.

5.2 Implicit prices of service characteristics

In this subsection, we offer an interpretation of the estimated parameters of the variables, or in other words the estimated implicit prices of the service features captured by them.

Download speed

Arguably, the most critical attribute of a broadband service is internet speed, with download speed proving to be a primary differentiator in the price of the internet plan. In the model selection process, we included upload speed as an explanatory variable, but found that it had a much lesser impact on prices compared to download speed. Moreover, to avoid multicollinearity arising from the joint inclusion of download speed, medium and upload speed, in the end we abandoned upload speed as an explanatory variable. In our final model, where we included download speed in logarithmic transformation to account for the diminishing returns at higher speeds, we measured a significant positive impact on the total plan price. The coefficient estimates demonstrate that a 10% increase in download speed correlates with an approximately 1% increase in the price of the plan throughout the examined periods, showing a slight, but continuous decrease (from 1.1% in 2020-21 to 0.9% in 2022-23). The significant role of download speed in the broadband price is in line with the findings of many former studies (see Greenstein and McDevitt, 2011, Calzada and Martinez-Santos, 2014, Corrrado and Ukhaneva, 2016, or Lyons and Coyne, 2016).

Medium of data transmission

The medium of data transmission also plays a significant role in fixed broadband pricing. Cable and especially, fibre networks offer the potential for higher internet speeds than the copper based xDSL technology. Simultaneously, more advanced technologies can transmit data more efficiently. Previous research found that these technologies are relatively cheaper than the xDSL (see, for example, Greenstein and McDevitt, 2011, Calzada and Martinez-Santos, 2014, Diaz-Pinés and Fanfalone, 2015, Corrrado and Ukhaneva, 2016, or Lyons and Coyne, 2016). In our model, we used cable internet as the benchmark technology because it's the most standard technology in the Hungarian market (xDSL is outdated and in decline, and fibre, while rising, is still limited in availability).

The estimation results for all three regressions confirm that xDSL is significantly more expensive than cable broadband in absolute terms. This mainly stems from the fact that xDSL can transmit at much lower maximum speeds, while ISPs do not price DSL plans significantly cheaper. The "copper surcharge" associated with xDSL technology is fluctuating between 20-28%. For optical fibre, the relative price tag is negative but either very low in value (around 2% in 2020-21) or not significant. This suggests that ISPs cannot price fibre plans significantly higher, presumably because consumers do not value this feature highly enough.

It is also important to highlight that the speed difference between xDSL and cable is primarily reflected in download speeds, but it is also noticeable, to a lesser extent, in upload speeds. However, the difference between cable and fibre is more apparent in the upload speed. Cable can transmit at higher speeds than DSL, but since most consumers prioritize download speeds over upload speeds, operators usually offer asymmetric plans with high download speeds and lower upload speeds. With fibre access, the capacity is much higher, enabling operators to offer more symmetric plans and much higher speeds up and down. In fact, in most cases, the difference in upload speed is solely due to the optical fibre as a medium. This explains why we did not consider upload speed as an explanatory variable in the final model, as its presence would have led to issues with multicollinearity.

Television

We also incorporated the characteristics of the other two services that can be bundled with broadband – television and fixed telephony – as we wanted to observe how these bundling features influence consumer prices in the case of multiplay bundles. Firstly, let us discuss the estimated coefficients related to the television service.

The most important attributes of a TV service are the number and video quality of channels included in the plan.[13] As we discussed earlier, we use a channel number index based on the quantity of SD and HD channels. This index is used in logarithmic form in our model, which assumes a decreasing marginal utility of channels. Nevertheless, since we intended to include those bundles in the estimation for which there was no television service (for which the channel index was set to 0), we applied the *ln(x+1)* transformation.[14] The estimated coefficient value reveals that a 10% increase in the channel number index led to a price hike of the bundle by around 0.8-1% throughout the period of study. In the final dataset, all the offered TV plans were transmitted through either IPTV or satellite, the latter being available in bundle only until 2022.

Regarding the bundled TV service, the price of the plan is influenced by the presence of additional video-related options selected for the plan. We incorporated these as dummy variables. The results suggest that both types of HBO packages, as well as the recording and video library options, have a significant positive impact on price. The validity of our estimation is backed by the fact that the calculated values closely align with the prices of the separate option prices as stated in the service providers' terms and conditions documents.

Voice services

When it comes to voice telephony service, the simple inclusion of this feature in a bundle inherently introduces an additional value, contributing to the total pricing of the package. This inherent value is derived from the fact that a telephony service user becomes an end node in the national telephony network, which means that even without initiating calls, they can receive them (in the Calling Party Pays system without cost). According to our regression results, the inclusion of the voice telephony service in a package exerts a substantial and significant influence on prices, increasing them by around 13-14% in all three pairs of years. Beyond the simple presence of the voice telephony service, we used its one characteristic that proved to be the most important supported by its significance and fit in the model selection, the nature of the minutes included in the bundle. Here, as discussed earlier, we measured the percentage of phone numbers in Hungary that can be reached by the favourable terms defined by the option. Some such plans offer unlimited calling, others contained a set number of minutes (sometimes provided as options). The common practice among providers for limiting minutes was a 100 minute cap.

As discussed before, the advantage of using this variable instead of a simple dummy indicating whether the plan includes minutes or not, is that this way we can more accurately represent the real value of this characteristic and capture the endogeneity between providers stemming from the network externality associated with the size of each provider's consumer base. To account for the non-linearity in their effect, we included these variables in logarithmic form. Both variables are highly significant and have a positive impact on the price of the plan. The coefficient for unlimited minutes suggests that if a consumer can call an

[13] Incorporating a separate indicator variable into the model would be redundant and cause serious multicollinearity. Each television package has several channels; therefore, a channel variable takes care of the presence of the TV subscription and also its size and quality.
[14] It is unlikely that this procedure would lead to significantly biased results, because if the bundle included a TV service, the channel number index was relatively high.

additional 10% more numbers without limitation, this would increase the price of the plan by roughly 0.3%. Similarly, if a consumer can use the 100 included minutes to call an additional 10 percentage points of numbers, this would increase the price of the plan by roughly.

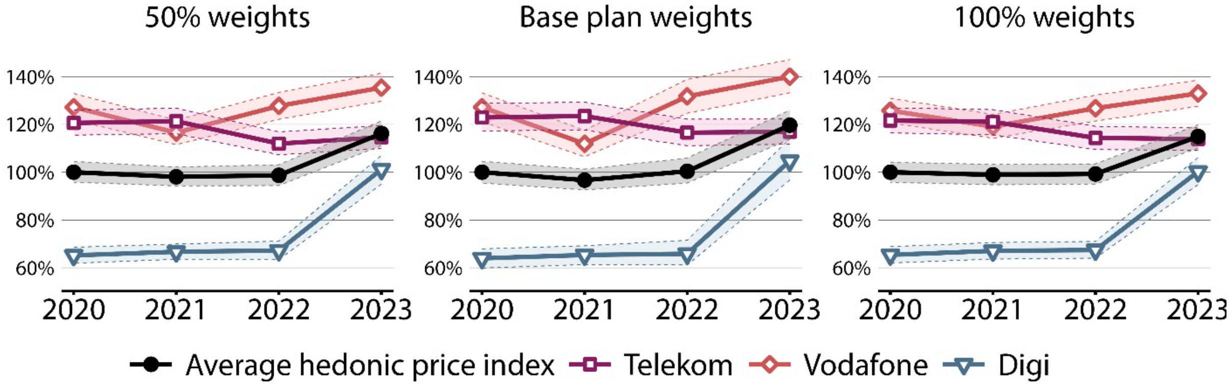
Discounts

There are three types of nationally available discounts recorded in our dataset: a loyalty discount, a discount for choosing the electronic paperless billing option, and a discount associated with bundling the mobile service with a fixed plan. Among these, the mobile discount is the highest, ranging between 13% and 20%. The discount for e-billing remains relatively stable throughout the period, with values around 7%. The loyalty discount ranges between 8% and 10% but is only significant at the 95% confidence level in the regression for 2020-2021.

5.3 Robustness

The weights used in estimation may significantly impact the results, so it is essential to verify their robustness using other potential weights. As discussed in Section 4, we generated two other weights for our observations in addition to the ones used in the main model, which balance between the base and option-complemented plans. One set of weights was calculated solely based on base plans (we call these "base plan weights"), and the other equally weighed all observations within each provider-plan type group (we call these "100% weights"), as we discussed it in Section 4.5. Results from the alternate models (shown in Table 5 of the Annex) corroborate the robustness of our main model, as the coefficients do not undergo substantial changes by the influence of alternative weights. For our main variables of interest (the yearly change in hedonic prices and the provider-specific price differences) the comparison between the alternative weighting systems and our chosen weights (labelled "50% weights") is shown by Figure 3.

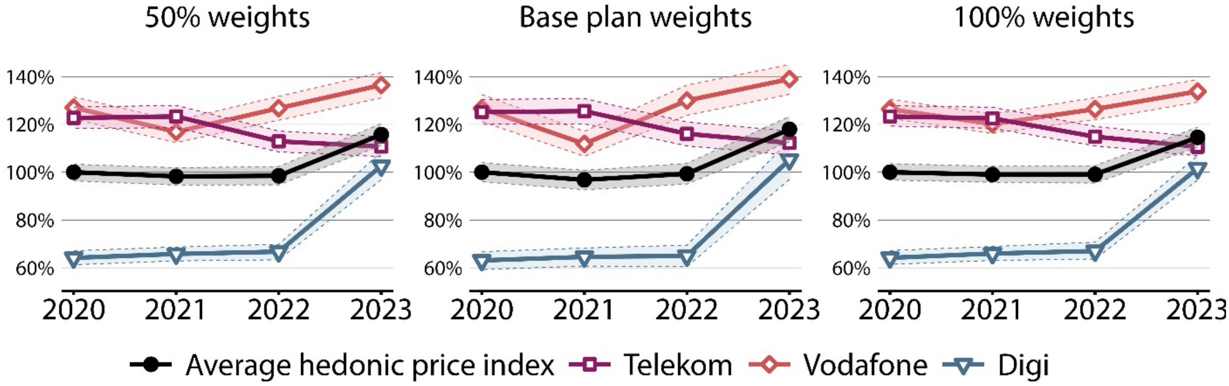
Figure 3: Estimated hedonic price indices in different weighting systems (2020 average = 100%)



As shown in the graphs, our main findings are confirmed by the results of both alterative models. In the case of base plan weights, we see slightly pronounced changes in time and differences between providers, while with 100% weights the changes and differences are smoother. For other variables less crucial for our analysis, we observe minor differences in the magnitude and significance of the estimated parameters, but none of the alternative models deviate significantly from the main model in their fundamental conclusions.

Another significant methodological decision was to estimate our models separately on samples of two adjacent years, rather than on the entire dataset, to ensure the time-flexibility of the estimated implicit prices of service characteristics. While this decision appeared methodologically sound, we aimed to verify whether our main results and conclusions remained consistent when estimating the model on a pooled sample. To address all possible combinations of modelling considerations, we estimated the pooled model using all three alternative weighting systems. Figure 4 illustrates the main results of the pooled model, focusing on the evolution of the hedonic price index and the provider-specific price differences.

Figure 4: Estimated hedonic price indices according to the pooled model (2020 average = 100%)



As seen in the figure, the differences compared to the baseline model are minor, the main results and conclusions are unchanged. The estimates for the service characteristics of the examined broadband plans show only a few small changes compared to the baseline model. The results of the pooled models are summarized by Table 6 in the Annex.

6. Conclusions and discussion

In this section, we put our results into context and discuss further questions and research opportunities that may arise.

The primary objective of this study was to quantify the quality-adjusted price changes in Hungarian broadband services and track the evolution of provider-specific price levels during a period of high inflation. Additionally, we sought to provide a comprehensive analysis of price dynamics following an unprecedented three-to-two merger in the Hungarian fixed broadband market, a merger that circumvented scrutiny by any competition or regulatory authority.

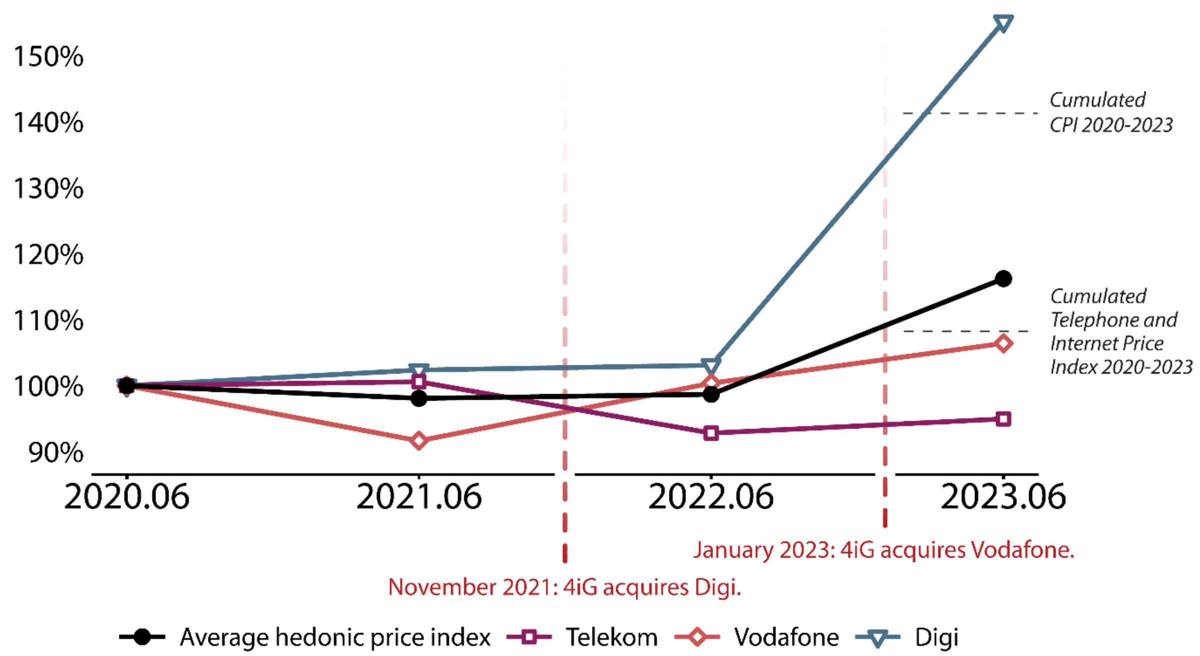
Utilizing publicly available data, this study offers a guide on data collection methodology. Employing the collected data, we applied a hedonic regression framework, meticulously evaluating methodological choices to ensure accurate and realistic measurement of quality-adjusted price changes. The insights gained from our data collection process and methodological considerations can be valuable for regulators in accelerating their price and market reporting processes and expanding them to include quality change assessments. Additionally, market players may find this information useful in developing efficient price monitoring systems using publicly available information.

Our results reveal a substantial realignment in the pricing strategies of the three main fixed broadband providers in Hungary. In 2020, Telekom and Vodafone positioned their fixed broadband services at similar price points, approximately 20% above the average market price, while Digi, then a challenger in the market, offered prices nearly 40% below average.

By mid-2022, Vodafone's hedonic prices increased slightly, coupled with a minor decrease in Telekom's prices. This shift positioned Vodafone as the most expensive provider in the country, with a statistically significant price premium. Notably, the average hedonic price level and Digi's prices remained stagnant during this period (2020-2022).

However, by 2023, Digi's prices surged by almost 50%, and Vodafone's upward price trend continued. Conversely, Telekom's hedonic prices decreased further. Consequently, Vodafone emerged as the most expensive provider, commanding an almost 20% premium over the average hedonic price. Telekom's prices aligned with the average hedonic prices, making the former incumbent’s offer become more favourable over the examined period. Despite the significant price increase, Digi remained the least expensive provider, but its discount relative to the average price level diminished considerably. While the absence of counterfactuals prevents us from establishing a direct causal link between the observed price upheaval and market consolidation, examining this evolution alongside inflation data from the Hungarian Central Statistical Office suggests that the price changes, particularly for the merged entities, may not be solely attributed to factors unrelated to the merger. Figure 5 illustrates the evolution of average and provider-specific price levels, with each time series indexed to its 2020 value (100%). The figure also presents cumulative inflation statistics for the overall economy and the telecom sector, along with the timing of key structural changes in the market detailed in subsection 3.2.

Figure 5: Hedonic broadband price levels in the context of inflation and market events



The figure illustrates that prices remained relatively stable until 2022, with Vodafone even experiencing a slight decrease by 2021. The acquisition of Invitech and Digi by 4iG in 2021 did not seem to immediately impact average prices.

The period between 2022 and 2023 marked a significant shift, with 4iG acquiring Vodafone in January 2023. By the middle of 2023, Digi's prices surged by 50%, surpassing the cumulative consumer price index for the 2020-2023 period. Vodafone also saw a further increase of nearly 10% in its hedonic price index. Combined, these increases pushed the estimated average hedonic price index above the telecom sector price index calculated by the Central Statistical Office. Notably, Telekom's offer became more and more favourable in the hedonic sense during the examined period. The hedonic method also allows us to see the implicit prices of various characteristics of the broadband plans, and how they change over time. These results are presented in detail in Section 5. The estimation concerning the medium of data transmission highlights the interaction between ISPs' pricing behaviour, local network availability and consumer preferences. Consumers value download speed, and care much less for the inherent quality of the medium. The slower xDSL is significantly more expensive than cable broadband in hedonic terms. This mainly stems from the fact that xDSL can transmit at much lower maximum speeds, while ISPs do not price xDSL plans significantly cheaper. The reason for this may be that in some given location, xDSL may be the only available technology, limiting true consumer choice. Meanwhile, for optical fibre, the price tag relative to cable is negative but not significant, despite the fact that optical fibre is the most advanced medium. Since fibre networks often overlap with other available technologies, this may suggest that this is rather the result of consumers' willingness to pay, meaning that they may not value the extra capabilities (like more symmetric upload speed) highly enough.

This study has demonstrated that the hedonic method is well suited to analyzing the fixed retail telecom markets and investigating several aspects of pricing behavior. The overall results provide opportunities for further discussion and extensions. A possible avenue for further research would be to continue recording the prices and features of the offered broadband plans. Future periods would allow for analysis when the two merged entities have consolidated into a single brand, offering unified pricing. Such an expanded study could provide valuable insights whether the observed significant price increase is a consequence of the foreseeable disappearance of the Digi brand or if it reflects a long-term pricing strategy for the new, unified entity.

There is also worth investigating the case of television, and to a lesser extent fixed telephony in a similar way to broadband: conducting the analysis on all possible plans that contain TV (or fixed telephony). Our database was already constructed to make this possible.

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Annex

Table 5: Estimation results of the hedonic regressions with alternative weights

	Dependent variable: Ln (Total Price)					
	Base plan weights			100% weights		
	20-21	**21-22**	**22-23**	**20-21**	**21-22**	**22-23**
Intercept	8.050 ***	8.065 ***	8.115 ***	8.135 ***	8.157 ***	8.184 ***
	(0.007)	(0.009)	(0.007)	(0.060)	(0.065)	(0.044)
Telekom	*0.206 ****	*0.257 ****	*0.179 ****	*0.196 ****	*0.207 ****	*0.168 ****
	(0.001)	*(0.001)*	*(0.002)*	*(0.011)*	*(0.018)*	*(0.022)*
Digi	-0.447 ***	-0.392 ***	-0.440 ***	-0.425 ***	-0.402 ***	-0.410 ***
	(0.001)	(0.001)	(0.002)	(0.011)	(0.015)	(0.023)
Vodafone	0.241 ***	0.135 ***	0.261 ***	0.229 ***	0.195 ***	0.242 ***
	(0.001)	(0.000)	(0.002)	(0.013)	(0.018)	(0.014)
2021	-0.034 ***			-0.011 ***		
	(0.000)			(0.002)		
Telekom 2021	*0.039 ****			*0.007*		
	(0.000)			*(0.007)*		
Digi 2021	0.055 ***			*0.037 ****		
	(0.000)			(0.003)		
Vodafone 2021	-0.094 ***			-0.044 ***		
	(0.000)			(0.004)		
2022		0.039 ***			0.003	
		(0.000)			(0.005)	
Telekom 2022		*-0.107 ****			*-0.066 ****	
		(0.000)			*(0.005)*	
Digi 2022		-0.029 ***			0.015	
		(0.001)			(0.019)	
Vodafone 2022		0.136 ***			0.050 *	
		(0.001)			(0.022)	
2023			0.176 ***			0.147 ***
			(0.001)			(0.006)
Telekom 2023			*-0.203 ****			*-0.177 ****
			(0.001)			*(0.010)*
Digi 2023			0.307 ***			0.273 ***
			(0.002)			(0.013)
Vodafone 2023			-0.104 ***			-0.096 ***
			(0.002)			(0.009)
Ln (Max Download Speed)	0.111 ***	0.099 ***	0.088 ***	0.102 ***	0.093 ***	0.086 ***
	(0.001)	(0.001)	(0.001)	(0.011)	(0.012)	(0.007)
Copper	0.268 ***	0.184 ***	0.204 ***	0.243 ***	0.180 ***	0.201 ***
	(0.003)	(0.005)	(0.005)	(0.029)	(0.042)	(0.050)
Fiber	-0.024 ***	-0.013 ***	-0.008 ***	-0.014 **	-0.006	-0.003
	(0.000)	(0.001)	(0.001)	(0.005)	(0.008)	(0.006)
Loyalty discount	-0.082 ***	-0.071 ***	-0.068 ***	-0.097 *	-0.085	-0.097 *
	(0.002)	(0.004)	(0.005)	(0.039)	(0.049)	(0.048)
E-discount	-0.074 ***	-0.070 ***	-0.069 ***	-0.062 ***	-0.061 ***	-0.059 ***
	(0.000)	(0.000)	(0.000)	(0.003)	(0.003)	(0.002)
Telephone	0.093 ***	0.094 ***	0.107 ***	0.148 ***	0.155 ***	0.166 ***
	(0.000)	(0.000)	(0.002)	(0.007)	(0.005)	(0.014)
Ln (Available number% unlim.)	0.048 ***	0.047 ***	0.046 ***	0.026 ***	0.024 ***	0.021 ***
	(0.000)	(0.000)	(0.000)	(0.005)	(0.004)	(0.002)
Ln (Available number% 100 min)	0.080 ***	0.098 ***		0.029 **	0.023 *	0.009 ***
	(0.001)	(0.000)		(0.011)	(0.011)	(0.002)
Ln (TV channel index)	0.085 ***	0.086 ***	0.099 ***	0.083 ***	0.088 ***	0.098 ***
	(0.000)	(0.000)	(0.000)	(0.003)	(0.004)	(0.004)
SAT TV	-0.086 ***	-0.021 ***		-0.053 ***	-0.011	
	(0.000)	(0.002)		(0.008)	(0.020)	
HBO		0.107 ***	0.107 ***	0.234 ***	0.225 ***	0.210 ***
		(0.000)	(0.001)	(0.022)	(0.025)	(0.021)
HBO Max	0.115 ***	0.130 ***	0.111 ***	0.250 ***	0.247 ***	0.246 ***
	(0.001)	(0.001)	(0.001)	(0.007)	(0.009)	(0.014)
Videotheque	-0.144 ***	-0.146 ***	-0.195 ***	0.099 ***	0.085 ***	0.073 ***
	(0.000)	(0.000)	(0.005)	(0.007)	(0.011)	(0.015)
Video recording			0.307 ***	0.090 ***	0.095 ***	0.108 ***
			(0.002)	(0.012)	(0.021)	(0.029)
Mobile included			-0.104 ***	-0.108 ***	-0.111 ***	-0.152 ***
			(0.002)	(0.002)	(0.002)	(0.041)
Number of Observations	3220	4300	4691	45222	52618	48867
Adjusted R2	0.88	0.88	0.86	0.89	0.89	0.89
AIC	-3097	-4189	-3711	-25256	-34561	-29789
F-statistic	1350	1652	1721	17947	22291	21418

Clustered standard errors in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05

Table 6: Estimation results of the pooled hedonic regressions with different weighting systems

	Dependent variable: Ln (Total Price)		
	50% weights	**Base plan weights**	**100% weights**
Intercept	8.145 ***	8.079 ***	8.160 ***
	(0.054)	(0.006)	(0.047)
Telekom	*0.205 ****	*0.225 ****	*0.210 ****
	(0.017)	*(0.001)*	*(0.012)*
Digi	-0.444 ***	-0.461 ***	-0.444 ***
	(0.011)	(0.001)	(0.009)
Vodafone	0.239 ***	0.237 ***	0.234 ***
	(0.011)	(0.001)	(0.009)
2021	-0.018 ***	-0.033 ***	-0.010 ***
	(0.002)	(0.000)	(0.002)
Telekom 2021	*0.023 ****	*0.036 ****	*0.003*
	(0.004)	*(0.000)*	*(0.005)*
Digi 2021	0.043 ***	0.056 ***	0.038 ***
	(0.002)	(0.000)	(0.002)
Vodafone 2021	-0.066 ***	-0.092 ***	-0.041 ***
	(0.003)	(0.000)	(0.003)
2022	-0.015 ***	-0.007 ***	-0.009 *
	(0.004)	(0.000)	(0.004)
Telekom 2022	*-0.068 ****	*-0.069 ****	*-0.062 ****
	(0.003)	*(0.000)*	*(0.003)*
Digi 2022	0.055 ***	0.037 ***	0.052 ***
	(0.014)	(0.001)	(0.014)
Vodafone 2022	0.013	0.032 ***	0.009
	(0.014)	(0.001)	(0.011)
2023	0.146 ***	0.165 ***	0.136 ***
	(0.008)	(0.001)	(0.008)
Telekom 2023	*-0.249 ****	*-0.274 ****	*-0.245 ****
	(0.005)	*(0.001)*	*(0.004)*
Digi 2023	0.324 ***	0.347 ***	0.324 ***
	(0.008)	(0.001)	(0.008)
Vodafone 2023	-0.075 ***	-0.073 ***	-0.079 ***
	(0.010)	(0.001)	(0.009)
Ln (Max Download Speed)	0.098 ***	0.101 ***	0.094 ***
	(0.010)	(0.001)	(0.009)
Copper	0.231 ***	0.237 ***	0.223 ***
	(0.041)	(0.004)	(0.039)
Fiber	-0.010 *	-0.016 ***	-0.008
	(0.005)	(0.000)	(0.004)
Loyalty discount	-0.086 **	-0.074 ***	-0.093 **
	(0.031)	(0.003)	(0.031)
E-discount	-0.064 ***	-0.072 ***	-0.061 ***
	(0.002)	(0.000)	(0.002)
Telephone	0.121 ***	0.097 ***	0.154 ***
	(0.006)	(0.001)	(0.007)
Ln (Available number% unlim.)	0.034 ***	0.047 ***	0.024 ***
	(0.003)	(0.000)	(0.003)
Ln (Available number% 100 min)	0.037 ***	0.080 ***	0.020 **
	(0.009)	(0.001)	(0.007)
Ln (TV channel index)	0.088 ***	0.092 ***	0.091 ***
	(0.003)	(0.000)	(0.003)
SAT TV	-0.082 *	-0.101 ***	-0.076 *
	(0.037)	(0.003)	(0.032)
HBO	0.226 ***	0.118 ***	0.222 ***
	(0.022)	(0.001)	(0.015)
HBO Max	0.269 ***		0.248 ***
	(0.011)		(0.008)
Videotheque	0.083 ***	0.114 ***	0.087 ***
	(0.012)	(0.001)	(0.008)
Video recording	0.097 ***	0.061 ***	0.097 ***
	(0.016)	(0.003)	(0.014)
Mobile included	-0.155 ***	-0.166 ***	-0.127 ***
	(0.029)	(0.002)	(0.018)
Number of Observations	94983	7911	94089
Adjusted R2	0.87	0.87	0.89
AIC	12782	-6637	-52487
F-statistic	25315	2049	28617

Clustered standard errors in parentheses. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$