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Recent trends in the Cypriot electronic communications sector[±]

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Abstract

The electronic communications sector has experienced rapid growth and dramatic change in recent years. We quantify the development of the sector in Cyprus in two ways. First, we measure the sector's contribution to economic output and provide comparisons with other European countries. The sector grew rapidly relative to the rest of the economy from 1995 until 2005 but much more slowly in the last decade. Second, we construct a price index for internet services using the hedonic methodology. Quality-adjusted prices of internet services dropped by 75% between 2005 and 2016, with most of the decline occurring between 2007-2012.

Keywords: Broadband; Internet access; Price index; DSL; Cable; Cyprus; Telecoms; Telecommunications.

1. Introduction

Communication and information services are critical components of an economy's infrastructure. They have become an integral part of everyday life as they are used by enterprises, consumers and public organisations. Society is becoming increasingly dependent on them as technology continues to develop rapidly and expand in new directions.

The electronic communications and information sector has changed dramatically over the past twenty years as a result of two main developments: rapid technological change and the introduction of competition. Technological change has led to large improvements in the quality and to a substantial expansion in the range of services offered. Market liberalization has encouraged investment and made the sector much more dynamic as firms continuously vie for market share.

[±] The paper summarizes findings from a joint project with the Office of the Commissioner for Electronic Communications & Postal Regulation (OCECPR).

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These developments have naturally affected Cyprus. The market was opened up to competition, new firms were established and new products were introduced. The increasing importance of telecommunication services is reflected in household expenditure. Average expenditure per household on telecom services was 3.22% in 2003 and 3.52% in 2009.[1] This figure is likely to continue to rise as consumers continue to shift towards high value services.

This study provides some measurements describing the evolution of the Cypriot electronic communications sector during this period of rapid change. A natural first step in assessing the sector's importance in economic terms is to measure its contribution to national output. We discuss this in section 2 and present calculations of telecoms' contribution to the Cypriot economy over a period of almost twenty years. As a basis for comparison we provide similar measures for other European countries and track their evolution over time.

The second step is the construction of a price index for internet services. Tracking price movements is important for policymakers in assessing market performance and adjusting the regulatory framework. It is also valuable to enterprises and individuals; to the latter for being able to compare and value their purchased services; and to the former for assessing market trends and accordingly pricing new products and technologies. At a more general level, price indices are important inputs in the work of statistical agencies as they are used as deflators in the construction of national accounts. In section 3 we report estimates of a price index for internet services. The index was constructed with original, detailed data collected from internet service providers and with the use of the hedonic methodology, which is considered more suitable than traditional matched-model approaches in markets experiencing rapid technological change.

[1] The figures are from the last two Household Budget Surveys. The Household Budget Survey is conducted by the national Statistical Service every five years, and the measured expenditures on telecommunication services include fixed and mobile telephony, as well as internet. Expenditures on internet access services are implicitly measured through the fixed and mobile telephony expenses.

2. The contribution of electronic communications to economic activity

There are various ways to measure the economic performance of a sector. The most common are (i) the sector's share of aggregate output; and (ii) the sector's contribution to the growth rate of the total output. Both measures are useful as they provide different information. We can think of the first one as a "stock" measure of the sector's size relative to the rest of the economy. The second one is a "flow" measure, as it focuses on the change in the sector's size.

There are two commonly used measures of aggregate output, Gross Domestic Product (GDP) and Total Gross Value Added (TGVA). GDP is an aggregate measure of production. It measures the monetary value of goods and services bought for final use, produced within a country in a given period of time. It counts all of the output generated within the borders of a country. It includes only final goods; it excludes intermediate consumption of goods and services, i.e. the value of raw materials, fuels and services that are used in the production process. It also includes some nonmarket production, such as education and defense services provided by the government, but excludes unreported productive activity like black market activities and unpaid work.

GDP is widely used by policy makers as a measure of economic activity and as an objective of economic policy. It is not a perfect measure of welfare for two main reasons. First, it does not include many aspects of quality of life, such as leisure activities; second, it is an aggregate measure that does not take into account income distribution. Despite these limitations, GDP correlates highly with quality-of-life indicators such as longevity and child mortality, and can thus be used as a proxy for welfare.

GDP can be calculated using one of three approaches: the output approach, the expenditure approach and the income approach. The output method constructs the *total gross value added* (TGVA) by adding the output from all the different sectors of the economy. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

GDP is obtained by adding import duties, taxes on imports, and the value added tax (VAT) to the TGVA. The expenditure method totals the final consumption of goods and services by residents. This comprises private consumption, gross capital formation, final consumption expenditure of government, plus exports minus imports of goods and services. Finally, the income approach sums the income of residents (individuals and firms) derived from the production of goods and services. In principle these three measures ought to be identical but in practice they rarely are because of statistical imperfections. For example, the expenditure approach can capture part of the unreported economic activity taking place in the black economy that – as noted earlier – is excluded from the output calculations.

By construction, GDP must exceed TGVA of all sectors of the economy, with the difference being taxes and duties. Using TGVA gives a more accurate representation of the underlying trends, since the measures will not be prone to changes due to tax rate deviations. In particular, GDP-related measures (M2 and M4 below), will be lower in magnitude in comparison to measures calculated with respect to TGVA (M1 and M3). Both measures are valid and the choice between them depends on the circumstances and on the type of information one is looking for. For most purposes, the qualitative conclusions will be the same. GDP is used more often in public policy debate because it is a more widely understood concept. For this reason it might be preferable to focus on GDP-related measures when analyzing sectoral performance, while keeping in mind that GDP contains a tax component and is therefore sensitive to changes in taxation. In the section below, the methodology of constructing the aforementioned measures is discussed in detail.

2.1. Measurement

2.1.1. Sectoral Performance Measures

To begin with, let us define the notions of total gross value added and gross domestic product using mathematical notation. Denote with GVA_t^n the gross value added of sector n at time t. By adding the gross value added for each of the N total sectors of the economy, we derive the total gross value added of the economy, that is: $TGVA_t = \sum_{n=1}^{N} GVA_t^n$. As noted above, when we add duties and taxes to the total gross value added, we end up with the gross domestic product of the economy: $GDP_t = TGVA_t + T_t$.

The first measure for monitoring the sectoral performance would be:

$$M_t^{1,n} = \frac{GVA_t^n}{TGVA_t} \tag{1}$$

Equivalently, we can also calculate the sector's share to the GDP. To do so, we replace the TGVA in the denominator of equation (1) with the GDP of period t, to obtain:

$$M_t^{2,n} = \frac{GVA_t^n}{GDP_t} \tag{2}$$

To measure the contribution of the sector to the growth rate, we need to calculate the following:

$$M_t^{3,n} = g_t^{GVA(n)} \cdot \frac{GVA_{t-1}^n}{TGVA_{t-1}} \tag{3}$$

where $g_t^{GVA(n)}$ is the growth rate of the gross value added for sector n at time t.

Equivalently, the contribution of a sector to the GDP growth would then be:

$$M_t^{4,n} = g_t^{GVA(n)} \cdot \frac{GVA_{t-1}^n}{GDP_{t-1}} \tag{4}$$

Derivation of measures (3) and (4) is not straightforward and is explained in Appendix A.

2.1.2. Inflation Adjustment

All output variables will have to be converted into constant terms in order for our estimates to be comparable across time. The sectoral GVA of the telecommunications sector in Cyprus was the only time series that we had to adjust for inflation since it was only available in current prices. All other total and sectoral output series for both Cyprus and its counterparts are accessible in constant 2005 prices directly from Eurostat's online database.

In order to create a time series of constant prices for the GVA of telecommunications, the best practice would be to adjust for inflation using the GVA deflator of the telecommunications sector. As this is not available, we turn to alternative measures. To adjust the market prices for inflation, we calculated the deflator of sector J, 'Information and Communication'.[2] An alternative would be to deflate the series using another related price index, for instance the consumer price index (CPI) for

[2] Sector '61. Telecommunications' is part of sector 'J. Information and Communication' in the NACE Rev. 2 classification system. To see what other sectors are included in sector J, and therefore all other sectors that will affect price movements in the J sector's GVA deflator, see section 2.2.

telecommunications. However, we have found that the deflator of sector J provides a better approximation of the GVA deflator for telecoms.[3]

Creating the series

Now that we have constructed a price index for the sector of interest, we can adjust the telecommunications GVA series for inflation, by simply dividing the series that is in nominal terms by the deflator of sector 'J. Information and Communication'. The deflated series is said to be measured in 'constant 2005 euros'. In general, to express a value from year Y in year X prices:

$$Year\ Y\ value * \frac{index.number.for.year.X}{index.number.for.year.Y} = year\ Y\ value\ in\ year\ X\ price.$$

The reciprocal of the fraction is the index value for year Y, where X is the reference year of the index, i.e. the index takes the value 100 at year X.

2.2. Data

Data for the overall economy as well as for the sector of telecommunications and its subdivisions whenever available were collected from the Eurostat website. In the NACE Rev. 2 classification system telecoms are part of sector J, 'Information and Communication'. At the two-digit level, sector 61 is Telecommunications. This is subdivided into the following groups: 61.1 Wired telecommunications activities, 61.2 Wireless telecommunications activities, 61.3 Satellite telecommunications activities, and 61.9 Other telecommunications activities.[4]

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[3] The correlation coefficient of deflator for sub-sector 61, and deflator for sector J for the EU27 countries between 2000 and 2012, that data are available, is 0.99, while the correlation coefficient of deflator for sub-sector 61 and the available HICP for telecoms for the same period and set of countries is 0.96. Note though that HICP is disaggregated into sub-sectors by means of consumption purpose (known as COICOP) as opposed to economic activity that the NACE classification is divided. As a result, the closest COICOP division to our 61 subsector of NACE, is the CP083 which includes 'Telephone and telefax services'. CP083 combined with the CP082 'Telephone and telefax equipment', they comprise CP08 'Communications' consumption disaggregation.

[4] Detailed information on what exactly each class of the three-digit activities, includes can be found on the book European Commission (2008), 'NACE Rev. 2 – Statistical classification of economic activities in the European Community', pp. 252-3 (accessible online via http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-015/EN/KS-RA-07-015-EN.PDF)

The exact variables used in the calculations of the sectoral performance measures are described in Table B1 in Appendix B. Data for most of the EU28 countries were collected in annual frequency. The quarterly series were used to construct the GVA deflator for sector J, for Cyprus. Our primary sample spans the period from 1995 to 2013; however, most countries have available data for all the series only up to 2012.

2.3. Analysis

The complete results of our calculations are presented in Appendix B (Table B2). In this section we use graphical means to display some of the main trends. Figure 1 shows the share of telecommunications in total gross value added for Cyprus in the period 1995-2012. The sector exhibited fast growth in the period 1995-2002 and experienced a temporary slowdown in 2003. Fast growth resumed in 2004, to be followed by a steeper and longer-lasting slowdown in 2006. Since then the sector has been growing at much slower rates than before, even contracting slightly in 2008, in line with the general economic slowdown. In terms of size relative to GDP or TGVA, the sector has yet to return to its 2005 peak.

FIGURE 1

Share of 61 on TGVA & GDP for Cyprus

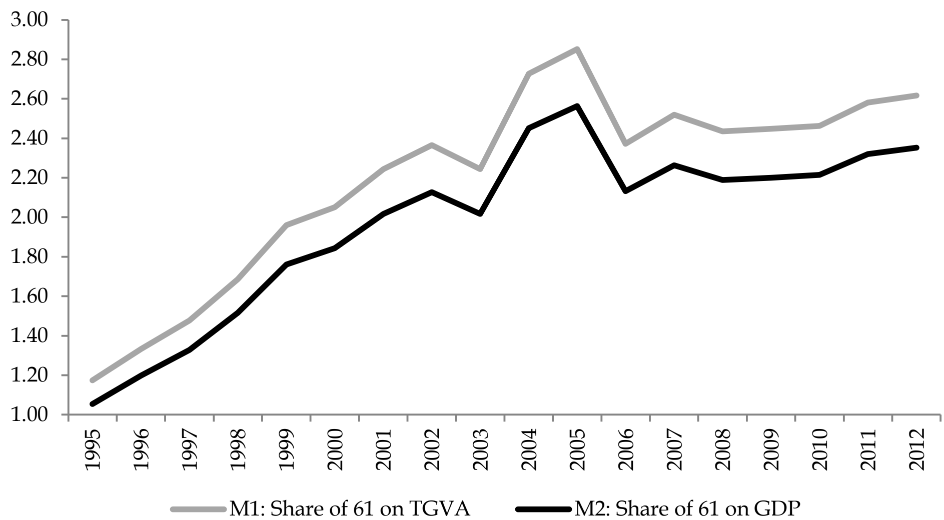


Figure 2 shows the telecom sector's contribution to the Cyprus growth rate. This was substantial in the period 1996-2005 (with the exception of 2003), but much smaller since. Looking at the most recent years, in 2012 telecommunications was among the sectors that drove overall economic activity down. By comparison, in 2011 telecoms had accounted for 0.13 percentage points of the national 0.44% TGVA growth rate.

FIGURE 2

Contribution of 61 on TGVA & GDP growth rate for Cyprus

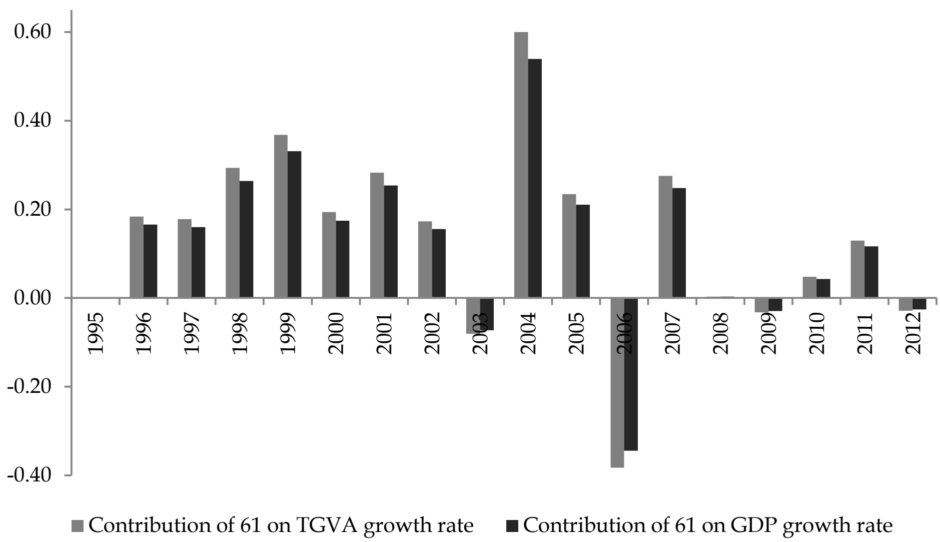


Figure 3 shows the share of telecoms in Cyprus and 23 other European countries for 2011 and 2012. The sector accounted for 2.62% of the overall Cypriot economy in 2012. The same figure for the EU27 was 2.27%, placing Cyprus above the European average. Figure 4 provides a picture of the sector's evolution throughout our sample period. It displays sector 61' share of TGVA in Cyprus, Greece, Estonia, and the EU27. Greece is included because of its proximity to Cyprus and Estonia because it is a small country (roughly the size of Cyprus) with an advanced information technology sector. Telecoms grow in significance over the period in all countries, although in the post-crisis period (since 2008) the sector seems to have flattened out in Cyprus and Greece. This is likely related to the deep recession in the two countries.

FIGURE 3

Share of telecommunications sector on TGVA, %

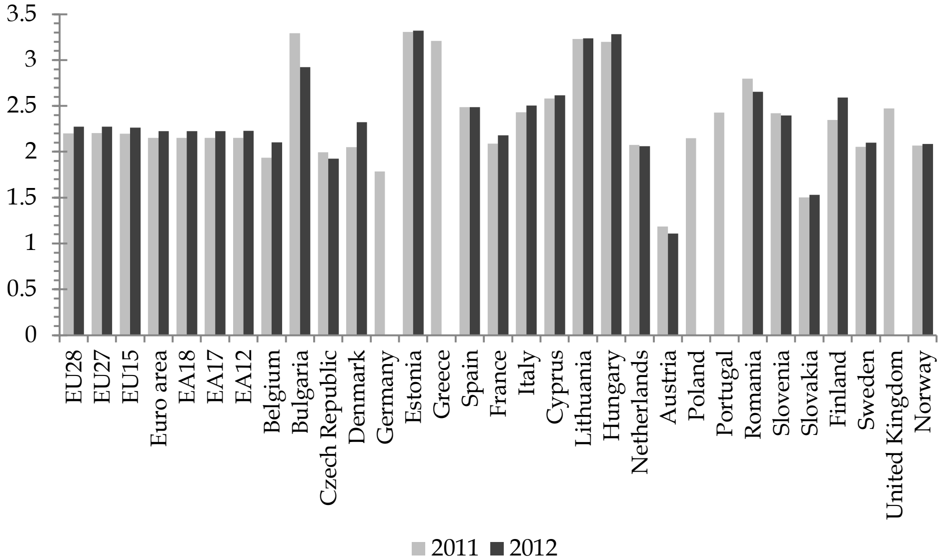
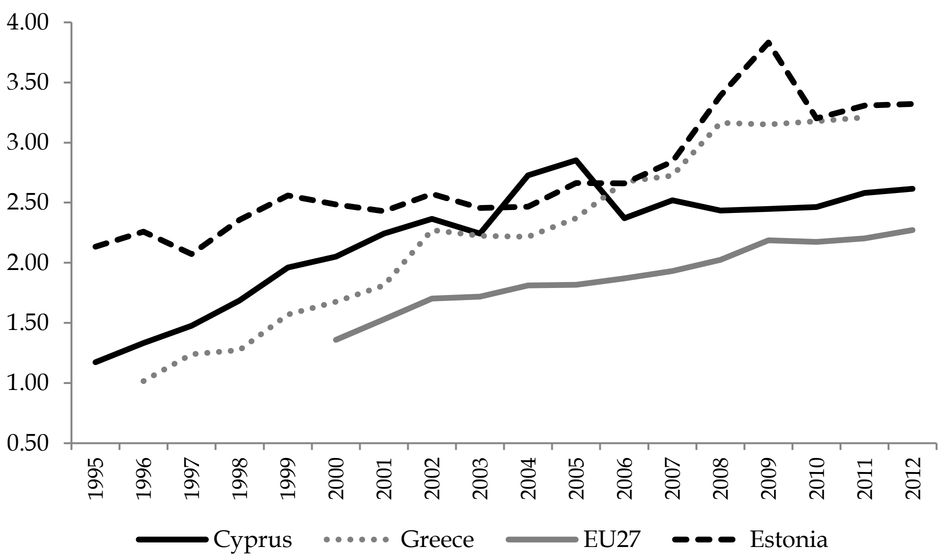


FIGURE 4

M1, Share of 61 on TGVA



The case of Greece is a good example to illustrate the importance of utilizing both the share and the contribution as means to measuring sectoral performance. In Figure 4 we observe an upward trend for the share of telecoms in Greece from 1995 to the end of the sample. In particular, for the years 2009 to 2011, there is an average annual increase of 0.92% in the share (M1). On the other hand, a look at the sector's contribution to aggregate output (M3) reveals that the sector actually shrank during the aforementioned period contributing an annual average decline of 0.13% to the total output. Therefore, the importance of the sectoral share is to give us a sense of the sectoral performance relative to the overall economy. By looking the figures and graphs for Greece we can conclude that telecom services contracted during 2009 to 2011, as a part of the overall recession.

3. A price index for internet services

The technological advancements of recent years have led to remarkable improvements in quality and a continuous expansion of the range of products and services offered to consumers. Obtaining an accurate picture of price developments in a sector that is in a continuous state of flux can be complicated. In this section we report the results of an effort to construct an accurate price index for internet access in Cyprus.

In measuring price changes care must be taken to account for changes in the quality of the provided products and services, otherwise price measurements become biased. A simple example of the abrupt change of the quality of the provided services is the replacement of regular dial-up with broadband internet connection that is up to a hundred times faster. Such improvements must be accounted as discounts in the expenditure of the consumer.

In a report commissioned by the US Bureau of Economic Analysis, Greenstein (2002) identifies some issues in the construction of CPI for internet access that require attention, and suggests various improvements. Among the areas the author highlights as requiring attention are adjustments for the increasing speed and the constant enrichment of contract features. Hedonic regression techniques have been developed for making direct price adjustments for quality change in indexes for various goods and services. Hedonic price indices (or quality adjusted indices) usually decline at a higher rate than indices that do not adjust for quality changes.

3.1. Constructing a price index: A simple illustration

A price index is a measure of the cost of a basket of goods (which could consist of a single good) at different points in time. More precisely, it is the price of the basket in the current period (t) relative to its price in the previous period ($t-1$). A simple and popular method of constructing an index is the matched-model method. It involves selecting a fixed basket of goods and calculating the cost of the same basket in successive periods. The cost of the basket is normalized to 100 in some base year. The price index at time t is simply the cost of the basket at time t divided by its price at the base year times 100. This is the main method used by statistical agencies.

The composition of the basket reflects consumer spending as measured in consumer surveys. As consumer spending patterns change over time, the basket must periodically be updated. The method works well if the characteristics of the goods and consumer spending patterns are relatively stable over time. It will not work well in a market where the composition of the basket is constantly changing because of (a) changes in the product set (introduction of new products and withdrawal of others); (b) changes in product characteristics; (c) introduction of new characteristics (dimensions of differentiation); and (d) changes in market shares.

In order to illustrate some of these issues we constructed a hypothetical example presented in Table 1. In year 1 there is a single product providing 10 units of quality (for an internet service this could be download speed) at a price of 20. The price per unit of quality is 20/10 = 2. If we choose year 1 to be our base year, then we set the price index (column PI) equal to 100 for year 1. For each future year we will divide the price per unit in that year by the price per unit in year 1 (=2) and multiply by 100 to obtain the price index PI.

Suppose that in year 2 the price increases to 25 while the quality stays the same. The new price-quality ratio is 2.5 (=25/10), which corresponds to a 25% increase in the PI. In year 3, quality improves from 10 to 15 but price remains the same, leading to a decline in the PI of 33.6%. This large decline would be missed if there was no adjustment for quality.

In year 4 a second product enters the market, offering the same quality at a lower price. We present two alternative measures of the PI. The first one is unweighted (it weighs the two products equally) and is obtained by taking the simple average of p1/x1 and p2/x2. The resulting PI indicates a price drop of 10%. Suppose, however, that product 1 has 90% of the market and product 2 only 10%. A more accurate index would take this into account by appropriately weighting the two price/quality ratios. The resulting weighted PI for year 4 reflects a much more modest decline of just 2%, as opposed to the 10% indicated by the unweighted PI.

TABLE 1

Construction of a price index

Year	x1	p1	p1/x1	q1	x2	p2	p2/x2	q2	PI	"Inflation"
1	10	20	2						100	
2	10	25	2.5						125	+25%
3	15	25	1.67						83	-33.6%
4	15	25	1.67		15	20	1.33		75	-10%
4	15	25	1.67	90	15	20	1.33	10	81.7	-2%
5	15	25	1.67	75	15	20	1.33	25	79.2	-3.1%

In year 5 both products remain unchanged in terms of price and quality but the market share of the new, cheaper product increases to 25%. This results in a PI decrease of 3.1%. The change in market shares led to a change in the PI even though prices and qualities have not changed.

This simple example illustrates that price indices are affected by changes in three factors: prices, quality (product characteristics), and relative market shares. In order to construct a precise price index, it is important for all three types of information to be available.

3.2. The hedonic methodology

As mentioned above, the matched-model method will perform well in mature markets with a stable set of products. It might be less appropriate for markets like telecommunications where technology is continuously evolving; products are changing and new products are being introduced; and market shares are unstable. The hedonic methodology has been advocated as a superior alternative for this type of market because it provides a systematic way of accounting for improvements in product characteristics over time. In particular, hedonic techniques allow us to estimate what the price the previous period $t-1$ would have been, had we included the improved characteristics in the product of period t.

The hedonic approach has primarily been used to construct quality adjusted price indices for houses (Hill 2011), automobiles (Griliches 1961), personal computers and other consumer electronics (Berndt *et al* 1995, and Berndt *et al* 2001). Depending on the nature of the product and the market, declines in the adjusted indices have ranged from 1% to even 15-20% and over per year. In particular, for internet access Stranger and Greenstein (2003), Yu and Prud'homme (2010), and Greenstein and McDevitt (2011) all showed that for the period under study a hedonic price index for internet access declined more that an index that does not account for quality change. Failure to adjust for quality changes therefore *underestimates* price index declines in markets with technological improvements.

The hedonic methodology consists of two steps. The first step involves the estimation of the hedonic function, which is usually a fairly simple specification of price as a function of product characteristics. In the second step, the estimates of the hedonic function are used to construct the price index using one (or more) of several available methods.

The hedonic function describes the relationship between prices of different varieties of heterogeneous goods and the quantities of the characteristics contained in them. Characteristics are either quantified whenever possible, or inserted as a binary variable to signal the existence of a particular characteristic (i.e. fixed telephony or TV). When estimating the hedonic function each product is treated as an aggregation of multiple clearly defined characteristics. The method produces a measure of the monetary effect of each characteristic on the final price. These effects are known as implicit or shadow prices of the product attributes.

After the hedonic function has been specified and estimated, the quality adjusted price index is constructed using the fitted prices. Since we break down the price of the products or services to their attributes, it is possible to evaluate the prices of different offers available in any of the sampled periods. The objective is to calculate price changes of products with constant quality and changing the characteristics vector can result in different indices. There is no consensus in the literature over an ideal index and each has its own properties. Some details about hedonic methods and the approach we adopt are provided in Appendix C.

Data requirements

Implementation of the hedonic methodology requires knowledge of the prices and characteristics of available products over the desired period of time. Suppose that we have $T+1$ periods indexed by $t=0,1,2,..,T$, where the first period, $t=0$, will serve as the reference period of the constructed indices.[5] In each period t there are N_t products available, each of which is characterized by a vector x_{jt} of K characteristics. There are M_t subscribers, each of whom will choose exactly one product. For the reasons explained in section 3.1, it is useful to also have the number of consumers q_{jt} who choose each item.

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[5] Depending on the frequency and properties of the available data, period t could represent any fraction of time, i.e. year, quarter or month.

There are two main approaches in specifying a hedonic function, the dummy variable method and the characteristics price method (Triplett, 2006). We explain each one in turn.

3.3. Data

A database containing all available internet access services offered in Cyprus was developed. The database spans the period from January 2005 to May 2016, and contains services from all four major telecommunication service proivders, namely Cablenet, Cyta, MTN, and PrimeTel. The companies provided us with information regarding the advertised price (in euros, including VAT), the underlying characteristics, as well as the availability period of every product they advertised and sold during the aforementioned period.[6] These were later arranged into a monthly format and various annual statistics were calculated and are presented below.

Table 2 shows the average number of packages per month marketed by each company in each of the reported years. Due to the monthly structure of the data, packages that are available in separate months are treated as different and therefore are counted as distinct packages. Nevertheless, Table 2 is informative since it clearly depicts the change in the volume of provided services, as well as when each of the companies entered the market of internet access provision.[7] In particular, Cyta was the primary seller of internet access services until 2006. In January 2006 Cablenet and Primetel made their first internet products available to consumers. In March 2014, MTN also entered the market for internet access services.[8]

[6] On January 1, 2008 Cyprus joined the euro area. All prices that were reported in Cyprus pounds were converted into euros using the following exchange rate: CYP 1 = EUR 1.708601.

[7] Note that the provided data for year 2016 include only the first half of the year (i.e. May 2016), therefore, any annual calculations for 2016 must be interpreted with cautiousness since they will only consider what is relevant until the first half of the year.

[8] MTN had also offered internet services during an earlier period (2008-2011) after it had acquired OTENET.

TABLE 2

Monthly number of offered packages by year and ISP

Year	Internet Service Providers				Total
	Cablenet	Cyta	MTN	PrimeTel	
2005	0	4	0	0	4
2006	4	4	0	7	15
2007	4	5	0	8	17
2008	6	4	0	3	13
2009	7	4	0	3	14
2010	7	4	0	4	15
2011	9	17	0	15	41
2012	11	24	0	18	53
2013	11	23	0	26	60
2014	11	24	49	20	104
2015	10	23	44	18	94
2016	9	12	24	28	73
Total	89	135	93	122	439

Source: Own calculations.

Table 3 reports descriptive statistics for selected variables of the sample covering the period 2005M1 – 2015M6. The total number of observations over this period is 5520, the mean price around 57 euro, and the mean download and upload speeds are 13 and 1 Mbps, respectively. Furthermore, 71% of the recorded internet access services are part of a bundle that also offers a fixed telephony service, 39% of the observations are sold as a bundle including TV, while 19% of the internet offers pertain to a bundle containing a mobile telephony service. For ease, and after the suggestion of some providers, we excluded older internet technologies that have become obsolete under the period we study. In particular, ISDN and dial up technologies were not included in the sample. As a result, services that are based on the DSL technology make up the majority of the sample, with 83%, while the rest advertised offers are based on cable and FTT technologies.

TABLE 3

Sample statistics (2005 – 2016)

Variables	Observations	Mean	Std. Deviation	Minimum	Maximum
Price	5520	57.18	23.09	15.50	175.99
VAT	5520	0.18	0.02	0.15	0.19
Download Speed (in Mbps)	5520	13.13	15.45	0.26	122.88
Upload Speed (in Mbps)	5520	0.99	1.07	0.06	8.19
Contract Duration	4570	16.65	5.63	12	24
Installation Charges	3381	69.06	44.90	0	131.00
Other Initial Charges	1297	23.84	22.47	0	45
Fixed Telephony	5520	0.71	0.45	0	1
Mobile Telephony	5520	0.19	0.39	0	1
TV	5520	0.39	0.49	0	1
Number of Channels	1096	42.97	12.02	16	81
Cablenet	5520	0.18	0.39	0	1
Cyta	5520	0.30	0.46	0	1
MTN	5520	0.22	0.42	0	1
Primetel	5520	0.29	0.45	0	1
Cable	5520	0.17	0.37	0	1
DSL	5520	0.83	0.37	0	1
FTT	5520	0.00	0.04	0	1

Source: Own calculations.

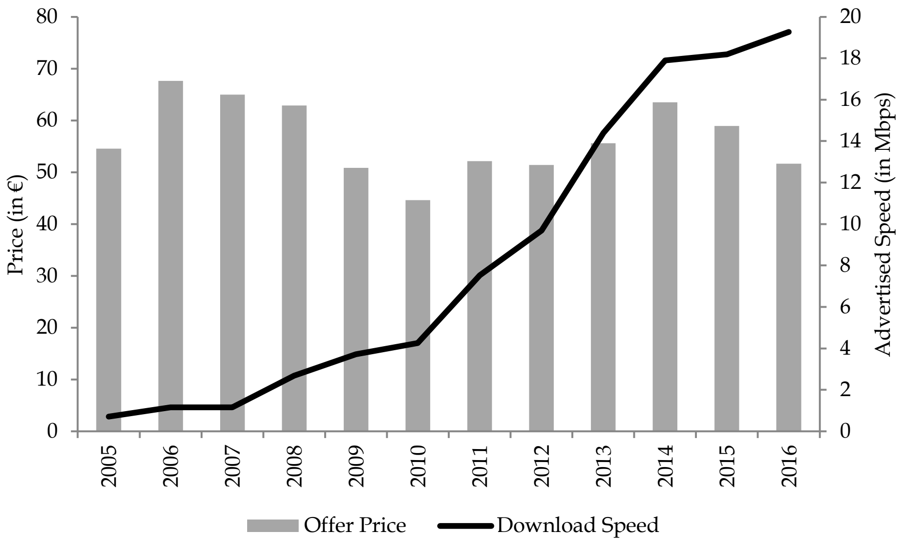
Figure 5 presents the average price and download speed for year 2005 to 2016. It also provides a graphical illustration of the need for quality adjustment in internet access prices, since the average download speed, among other quality characteristics, is constantly changing over time. As already explained in previous sections, we address the issue of improving quality by estimating price changes controlling for changes in the attributes of the offered service. Thus, the estimated price changes over time pertain to offers with the same download speed, as well as the same quantity or quality on any of the other characteristics.

Removal of outliers

Additionally to the aforementioned smoothing technique, in order to further ensure representativeness in the absence of subscriber statistics, and avoid services that are targeting extreme groups of consumers, we employed an outlier removal technique that is based on the minimum price. In particular, observations that were found to be six times higher than the minimum price per month and per service provider were removed from the sample. Other standard statistical practices of excluding observations with three or more standard deviations from the mean were also used, giving similar results.

FIGURE 5

Average price and download speed



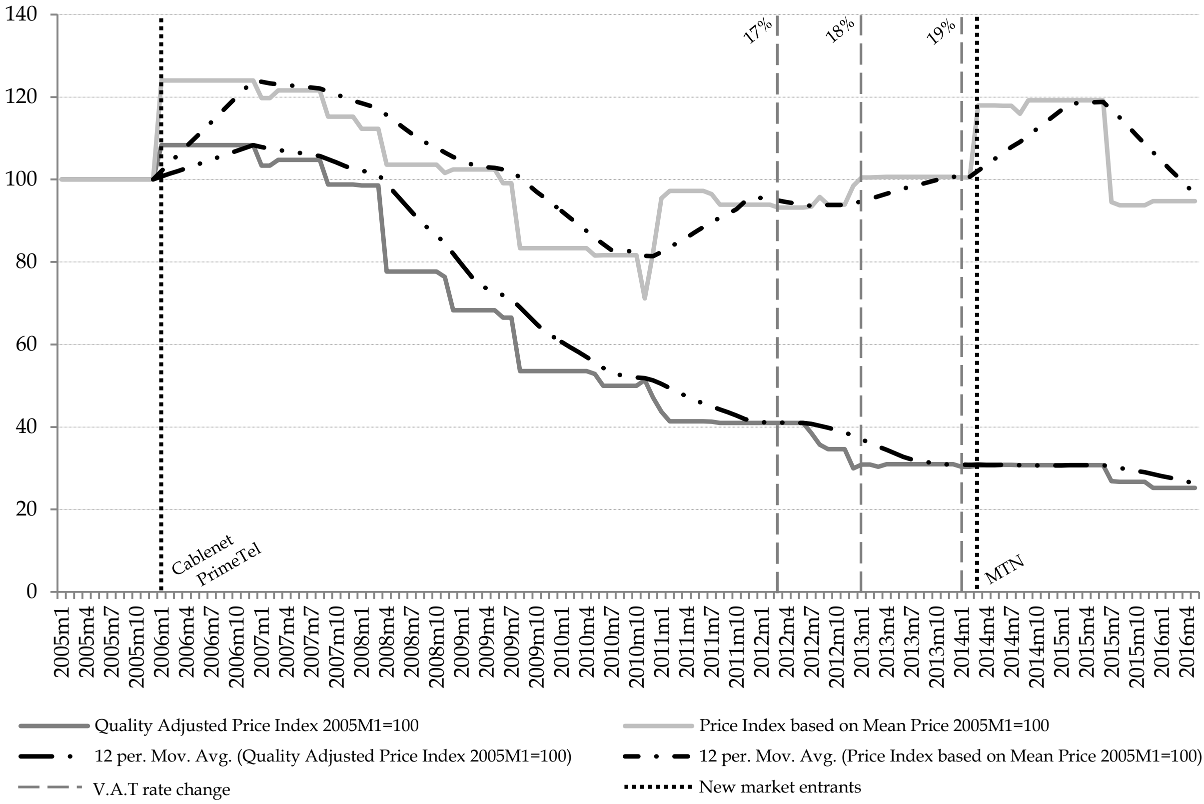
An example that well illustrates the point that we need to remove outliers is the monthly rate of a 10 Mbps internet connection (sold as bundle with TV) in early 2008 that can exceed 300 euros. As a matter of fact the estimated mean price change can be affected from these offers entering or exiting the sample. Had we subscriber data available, we would have known the exact percentage of consumers who bought this highly priced bundle. In the absence of such data though, and in order to avoid implausible assumptions regarding the popularity of certain 'extreme' offers, we employ the aforementioned outlier removal technique to remove these from the sample.

3.4. Estimated price indices for internet access

Figure 6 shows the evolution of the quality adjusted price index for internet access in Cyprus over the period 2005M1-2016M5, as estimated using the methods and data described above. The solid line is a simple index constructed based on the average price per month and the blue line the quality adjusted price index one. The two dotted lines represent the underlying MA12 smoothed indices. The price index that is based on the average price is a further illustration of the fact that the observed price of provided services might rise, but since the actual provided services are getting better, the final adjusted prices are in fact decreasing.

FIGURE 6

Price indices for internet access, 2005M1-2016M5



The index shows the average cost of supplied services per month. The average offered internet access service has seen a price decline over the period sampled. However, since the index does not include any information on consumers' purchases, we cannot draw any conclusions regarding the evolution of actual prices paid by consumers. In other words, the average quality-adjusted price of internet service has decreased, but consumers may be choosing higher quality and paying the same or even higher prices. This is likely to be the case as most of the declines in quality-adjusted price are due to quality increases rather than price decreases.

It is therefore important that we distinguish between the cost of offered services and the cost incurred by the consumer. Under the assumption that consumer preferences have remained constant over the period under study, the two notions will coincide. This, however, is unlikely, as most studies find that the typical consumer purchase improves over time at roughly the same rate as overall technological progress.

Table 4 shows the level and the percentage change of the annual adjusted price index for internet access services. The annual index is computed directly as the twelve month average from the monthly adjusted index. From 2005 to 2016, the average internet access package has decreased by 11.3% annually. From 2008 to 2011, the average annual decrease of the adjusted index was 20.2%, signaling a mixture of decreases in unadjusted prices and rapid increases in the quality characteristics of the average offered service during that period. Since 2014 prices have somewhat stabilized compared to the past. In 2015 the annual change was -6.7%, while in 2016 prices went down by 11.6%.

TABLE 4

Annual index for internet access and percentage change, 2005-2016

Year	Quality adjusted price index 2005=100	% Change
2005	100.0	-
2006	108.3	8.3%
2007	102.5	-5.3%
2008	82.0	-20.0%
2009	61.8	-24.6%
2010	51.3	-17.1%
2011	41.4	-19.3%
2012	37.8	-8.6%
2013	30.9	-18.2%
2014	30.6	-0.9%
2015	28.6	-6.7%
2016	25.3	-11.6%

Source: Own calculations.

The increase that took place between 2005 and 2006 needs further investigation, in order to understand whether it is a result of an overall increase in prices, a decrease in the quality, a mixture of the two, or an overoptimistic marketing comprised of highly priced offers from the two market entrants, namely Cablenet and PrimeTel, that entered the market in early 2006, in an effort to capture customers from the incumbent firm that were willing to pay more for an improved service. Digging deeper into the data we see that the average package offered by Cyta in 2005 and 2006 is effectively the same, and that the overall price increase originates solely from the two entrants. These two facts suggest the latter explanation and only inclusion of subscriber statistics can shed further light into whether consumers' costs actually rose during the period in question.

4. Summary

Telecommunications has been one of the fastest growing sectors worldwide in recent years. In Cyprus, the broader telecommunication sector grew from just over 1% of GDP in 1995 to about 2.5% in 2005, but has since contracted somewhat and stood at 2.35% in 2012. During this period it contributed to the growth of the Cypriot economy. The relative size of the sector in Cyprus is higher than the European Union average, which is 2.04%. This may be partly attributed to the small size of the Cypriot economy and to the fact that internet service in Cyprus is the most expensive in Europe, especially at speeds above 12mbps.[9] Telecoms require substantial investments in infrastructure that are mostly fixed, and as a result small countries are likely to have larger sectors than larger countries with similar characteristics. Given the prolonged period of slow growth, one might expect much higher growth once overall economic activity recovers.

In the second part of the paper we present a price index for broadband services in Cyprus. The index is normalized at 100 in 2005, the beginning of the sample period. It remained fairly stable until the end of 2007, and then started a gradual decline that dropped it to about 40 at the beginning of 2011. A further decline in the second half of 2012 dropped the index to about 30. It remained at the same level until mid-2015, and dropped to about 25 thereafter.

A few points are worth highlighting. The entry into the market of two competitors in 2006 did not result in any immediate downward pressure

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[9] See European Union's Digital Economy & Society Index (DESI) report, available at https://ec.europa.eu/digital-single-market/en/desi.

on the price index. Rather, the index rose because the entrants aimed for the high end of the market. There is a sharp drop of 20 points in the index in the beginning of 2008 and is likely the result of technological upgrades.

The index remained essentially flat from the beginning of 2013 until late 2015. The entry of a new player in 2014 did not have any noticeable impact, at least immediately. Competition seems to have stabilized and market participants are not willing to risk bold pricing moves. Competition for market share is primarily conducted in terms of quality rather than prices. This is reflected in the data, where we observe that the mean price has been more or less stable during this ten year period. It would likely take a major exogenous event such as technological advances or the entry of a new competitor (or a quasi-new competitor in the form of Cyta's privatization) to produce significant further declines in the price index.

Appendix

A. Methodology for the construction of performance indicators

To calculate the contribution of a sector to the total GVA growth rate we have to decompose the growth rate of the TGVA to its components i.e. the sectoral outputs. To begin with we define the growth rate of the total gross value added for the economy and following some calculation we end up with the summation of what we earlier defined as $M_t^{3,n}$.

$$g_t^{TGVA} = \frac{TGVA_t - TGVA_{t-1}}{TGVA_{t-1}} = \frac{\sum_{n=1}^{N} GVA_t^n - \sum_{n=1}^{N} GVA_{t-1}^n}{TGVA_{t-1}} = \sum_{n=1}^{N} \frac{GVA_t^n - GVA_{t-1}^n}{TGVA_{t-1}} =$$

$$\sum_{n=1}^{N} \frac{GVA_t^n - GVA_{t-1}^n}{TGVA_{t-1}} \cdot \frac{GVA_{t-1}^n}{GVA_{t-1}^n} = \sum_{n=1}^{N} \frac{GVA_t^n - GVA_{t-1}^n}{GVA_{t-1}^n} \cdot \frac{GVA_{t-1}^n}{TGVA_{t-1}} =$$

$$\sum_{n=1}^{N} g_t^{GVA(n)} \cdot \frac{GVA_{t-1}^n}{TGVA_{t-1}} = \sum_{n=1}^{N} M_t^{3,n}.$$

In the same manner we can also calculate the contribution of the sector to the GDP growth.

$$g_t^{GDP} = \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}} = \frac{TGVA_t + T_t - (TGVA_{t-1} + T_{t-1})}{GDP_{t-1}} =$$

$$\frac{\sum_{n=1}^{N} GVA_t^n + T_t - (\sum_{n=1}^{N} GVA_{t-1}^n + T_{t-1})}{GDP_{t-1}} = \sum_{n=1}^{N} \frac{GVA_t^n - GVA_{t-1}^n}{GDP_{t-1}} + \frac{T_t - T_{t-1}}{GDP_{t-1}} =$$

$$\sum_{n=1}^{N} \frac{GVA_t^n - GVA_{t-1}^n}{GDP_{t-1}} \cdot \frac{GVA_{t-1}^n}{GVA_{t-1}^n} + \frac{T_t - T_{t-1}}{GDP_{t-1}} = \sum_{n=1}^{N} g_t^{GVA(n)} \cdot \frac{GVA_{t-1}^n}{GDP_{t-1}} + \frac{T_t - T_{t-1}}{GDP_{t-1}} =$$

$$\sum_{n=1}^{N} M_t^{4,n} + \frac{T_t - T_{t-1}}{GDP_{t-1}},$$

If we assume that duties and taxes are a linear function of the GDP, and that are constant across time, that is $\tau_{t-1} = \tau_t = \tau$, the above expression simplifies to:

$$\sum_{n=1}^{N} M_t^{4,n} + \tau g_t^{GDP} .$$

B. Additional tables and graphs for section 2

TABLE B1

Source and description of variables

Variable	**Sector (NACE v2)**	**Online data code - Eurostat**	**Frequency**	**Description (units, currency, seasonal adjustment)**
Gross domestic product	-	nama_gdp_k	annual	Million euro, chain-linked volumes, reference year 2005 (at 2005 exchange rates)
Gross value added, current prices	61 Telecommunications	nama_nace64_c	annual	Millions of euro (from 1.1.1999)/Millions of ECU (up to 31.12.1998)
Gross value added, volumes	Total	nama_nace64_k	annual	Millions of euro, chain-linked volumes, reference year 2005 (at 2005 exchange rates)
Gross value added, current prices	J Information and communication	namq_nace10_c	quarterly	Millions of euro (from 1.1.1999)/Millions of ECU (up to 31.12.1998), Not Seasonally Adjusted
Gross value added, volumes	J Information and communication	namq_nace10_k	quarterly	Million euro, chain-linked volumes, reference year 2005 (at 2005 exchange rates), Not Seasonally Adjusted

TABLE B2

Economic performance measures for Cyprus telecom sector

Indicator	M1:	M2:	M3:	M4:			
Variable Name	Share of 61 in TGVA	Share of 61 in GDP	Contribution of 61 to TGVA growth rate	Contribution of 61 to GDP growth rate	61 GVA growth rate	TGVA growth rate	GDP growth rate
1995	1.17	1.05					
1996	1.33	1.20	0.18	0.17	15.68	1.82	1.82
1997	1.48	1.33	0.18	0.16	13.36	2.33	2.33
1998	1.69	1.52	0.29	0.26	19.87	4.98	4.98
1999	1.96	1.76	0.37	0.33	21.83	4.83	4.82
2000	2.05	1.84	0.19	0.17	9.91	5.01	5.01
2001	2.24	2.02	0.28	0.25	13.77	4.02	4.02
2002	2.37	2.13	0.17	0.16	7.72	2.13	2.13
2003	2.24	2.02	-0.08	-0.07	-3.40	1.87	1.87
2004	2.73	2.45	0.60	0.54	26.73	4.24	4.24
2005	2.85	2.56	0.23	0.21	8.58	3.85	3.86
2006	2.37	2.13	-0.38	-0.34	-13.42	4.13	4.13
2007	2.52	2.26	0.28	0.25	11.63	5.09	5.09
2008	2.43	2.19	0.00	0.00	0.14	3.59	3.59
2009	2.45	2.20	-0.03	-0.03	-1.34	-1.85	-1.85
2010	2.46	2.21	0.05	0.04	1.96	1.31	1.31
2011	2.58	2.32	0.13	0.12	5.26	0.44	0.44
2012	2.62	2.35	-0.03	-0.03	-1.11	-2.41	-2.41

TABLE B3

Economic performance measures for telecom sector - EU average

Indicator	M1:	M2:	M3:	M4:			
Variable Name	Share of 61 on TGVA	Share of 61 on GDP	Contribution of 61 on TGVA growth rate	Contribution of 61 on GDP growth rate	61 GVA growth rate	TGVA growth rate	GDP growth rate
1996						1.78	1.88
1997						2.72	2.85
1998						2.90	2.94
1999						2.87	2.93
2000	1.36	1.21				3.83	3.91
2001	1.53	1.36	0.20	0.18	14.61	2.02	2.00
2002	1.70	1.52	0.20	0.18	12.89	1.26	1.26
2003	1.72	1.53	0.04	0.03	2.26	1.45	1.48
2004	1.81	1.62	0.14	0.13	8.32	2.66	2.57
2005	1.82	1.62	0.04	0.04	2.38	2.17	2.16
2006	1.87	1.67	0.12	0.10	6.44	3.37	3.36
2007	1.93	1.73	0.13	0.11	6.75	3.40	3.20
2008	2.02	1.82	0.10	0.09	5.43	0.57	0.37
2009	2.19	1.96	0.06	0.06	3.15	-4.54	-4.50
2010	2.17	1.95	0.03	0.03	1.40	2.07	2.03
2011	2.20	1.98	0.07	0.06	3.18	1.80	1.66
2012	2.27	2.04	0.06	0.06	2.89	-0.28	-0.38

C. The hedonic methodology

C.1. The dummy variable method

The most commonly used approach is the dummy variable method. It pools together data from all periods and estimates a hedonic function that is constant over time except for a time fixed effect that is common among products:

$$\ln p_{jt} = \alpha_0 + \alpha' x_{jt} + \sum_{\tau=1}^{T} \delta_\tau D_{j\tau} + u_{jt} \qquad \text{(C1)}$$

with

$$\alpha' = [\alpha_1, \alpha_2, \dots, \alpha_K]$$

$$x_{jt} = \left[x_{jt}^1, x_{jt}^2, \dots, x_{jt}^K\right]'$$

The dependent variable $\ln p_j$ is the logarithm of the price (in euros) of service j in period t, ε_{jt} is the random error term of the model, and x_{jt} is a vector of the attributes of each available service. Any price–determining characteristics of the product can be included in the x_{jt} vector. For instance in the case of the internet access services, some of the attributes are: connection speed (bandwidth), number of email accounts and the provided web page storage utilities, and contract length. In addition, it is possible to also have dummy variables indicating whether or not the service is part of a bundle with fixed telephony or TV, whether or not the package includes a DSL or a cable connection, and firm specific dummies to include any preferences or costs reflected in the price that are due to a specific ISP.

This method has been widely used because of its simplicity it terms of constructing the index (see below) and because it has lower data requirements than other methods. A common criticism of the method is that it constrains coefficients to be constant over time. Depending on data availability, this can be addressed by generalizing equation (2) so that the coefficients on some (but not all) characteristics are allowed to vary over time. For example, if the researcher believes that download speed is particularly important he can allow for a time-specific coefficient on that while keeping all other coefficients fixed.

Index construction with the dummy variable method

Following the estimation of equation (C1), the fitted log price of a particular service with characteristics x_{jt} at time t can be obtained:

$$\widehat{\ln p}_{jt} = \hat{\alpha}_0 + \hat{\alpha}' x_{jt} + \hat{\delta}_t$$

for $t = 1, 2, \dots, T$. The price index, P^{0t}, is then computed by dividing the exponentiated fitted values in each period by those corresponding to the reference period $t = 0$.

$$P^{0t} = \frac{\hat{p}_{i(t)}}{\hat{p}_{i(0)}} = \frac{exp\ \hat{\alpha}_0 \cdot exp\ \hat{\alpha}' x_{i(t)} \cdot exp\ \hat{\delta}_t}{exp\ \hat{\alpha}_0 \cdot exp\ \hat{\alpha}' x_{i(t)}} = exp\ \hat{\delta}_t$$

for every $t \in \{0, 1, 2, \dots, T\}$. The index for period t is therefore the exponentiated coefficient of the dummy variable representing period t. Note though that the choise of x here is irrelevant. That is because as long as we have the same product between the two comparison periods (i.e. same x in period t and the reference period $t = 0$), the two terms in the fraction will cancel out.

C.2. The characteristics price method

The second approach goes by various names but is most commonly referred to as the characteristics price approach. It specifies a general hedonic function of the form:

$$\ln p_{jt} = \beta_{0t} + {\beta_t}' x_{jt} + \varepsilon_{jt} \tag{C2}$$

with

$$\beta' = [\beta_{1t}, \beta_{2t}, \dots, \beta_{Kt}]$$

$$x_j = \left[x_{jt}^1, x_{jt}^2, \dots, x_{jt}^K\right]'$$

Equation (C2) differs from equation (C1) in that it has time-varying β coefficients and no time dummies. Provided enough data points per period are available, the way to proceed is to estimate equation (C2) separately for each period and thus obtain $T + 1$ hedonic functions.

If data are limited, it is possible to estimate what is known in the literature as adjacent period regressions. This approach pools together every pair of adjacent periods and estimates a single hedonic function containing one time dummy variable for the pair. As long as the dependent variable in these regressions is expressed in natural logarithms, the coefficient of the time dummy will indicate the percentage change in quality adjusted prices between the two periods. The adjacent period regression approach is in essence a hybrid of the time dummy method and the characteristics price method.

Index construction with characteristics price method

To construct the index we first need to compute the predicted log price, $\widehat{\ln p_j}$.

$$\widehat{\ln p_j} = \hat{\beta}_0 + \hat{\beta}' x_j$$

A realization of the predicted price is then retreived by taking the exponential on both sides of the equation above:[10]

$$\hat{p}_j = exp\left[\, \hat{\beta}_0 + \hat{\beta}' x_j\right]$$

In order to construct an index, P^{0t}, with period $t = 0$ as the reference period, we need to take the price relative of any period t with respect to $t = 0$. The predicted prices however, have to be computed for a particular x_j. Referring back to the notion that price indices need to compare the prices of a standartized product, here rises the question of what x_j would be appropriate. There are three distinct indices that can be found in the literature, each with its own properties. The three indices are the Laspeyres Index, the Paasche Index and the Fisher Index. Laspeyres price index uses the characteristics of all purchased services in the base period to compute the predicted prices. For the Paasche index we take the characteristics from the current period subscriptions.[11]

$$P^{0t}_{Laspeyres} = \frac{\sum_{j \in M(0)} \hat{p}^t_j}{\sum_{j \in M(0)} \hat{p}^0_j} = \frac{\sum_{j \in M(0)} exp\left[\, \hat{\beta}^t_0 + \hat{\beta}^{t\prime} x_j\right]}{\sum_{j \in M(0)} exp\left[\, \hat{\beta}^0_0 + \hat{\beta}^{0\prime} x_j\right]}$$

$$P^{0t}_{Paasche} = \frac{\sum_{j \in M(t)} \hat{p}^t_j}{\sum_{j \in M(t)} \hat{p}^0_j} = \frac{\sum_{j \in M(t)} exp\left[\, \hat{\beta}^t_0 + \hat{\beta}^{t\prime} x_j\right]}{\sum_{j \in M(t)} exp\left[\, \hat{\beta}^0_0 + \hat{\beta}^{0\prime} x_j\right]}$$

for $t \in \{0, 1, 2, \dots, T\}$. The Laspeyres and Paasche indices are sensitive to selected reference characteristics (see Yu and Prud'homme, 2010) with the former ignoring the introduction of improved characteristics and the latter not taking into account disappearing attributes. It is therefore common practice to take the geometric mean of the two, which is known as the Fisher index:

$$P^{0t}_{Fisher} = \sqrt{P^{0t}_{Laspeyres} \times P^{0t}_{Paasche}}$$

[10] Note that $e^{\widehat{\ln p_j}} \neq \hat{p}_j$, however it is approximately the same.

[11] Since with this method we estimate equation (1) multiple times, one for every period in the sample, superscripts in the predicted price $\hat{p}^t$ and the coefficients $\hat{\beta}^t$ are needed in order to distinguish the regression model that estimated coefficients originate from. Therefore, coefficients having superscript t have been estimated using solely the sample of period t. Likewise, predicted prices with superscript t, have been calculated using the coefficient estimates produced from regressing the sample of period t only.

Smoothing

After the price index has been estimated for each month as described above, for illustration purposes we construct a twelve-period moving average (MA12) series. This helps us smooth 'spikes' in the data that arise from the large variation among the characteristics of the available products and the absence of subscriber statistics and, possibly, seasonality. The smoothed index is given by:

$$\bar{P}_t = \frac{1}{12}(P^{0t} + P^{0t-1} + P^{0t-2} + \cdots + P^{0t-11}), \text{ for } t \geq 11.$$

Note thought that in order for the smoothed index to be used as a representative index, it needs to be rebased to a period of preference. Otherwise, in order to utilize it solely for illustration purposes, it can be used as is.

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