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COMPARING SERVICE PRICES AMONG PROVIDERS AND TARIFF PLANS

Price Index Concepts for Mobile Communication, Public Transport and Basic Services in Switzerland

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Abstract

Providers of widely used services offer various tariff plans to consumers, such as different cell phone contracts for mobile communication or train tickets for public transport services. The service prices are thus dependent not only on the consumption but also on the underlying tariff plan. Comparisons of these service prices are commonly biased because tariff plans are not implemented correctly.

This thesis offers new concepts to compare service prices among providers and time periods. Since tariff plans and data structures are unique in most services, customised approaches are required. For mobile communication, a hedonic price index based on monthly bills is employed. The price development in public transport is measured by average travelled kilometers. Basic service prices across municipalities are compared via household consumption profiles.

The concepts are motivated practically, described formally and illustrated empirically.

Acknowledgements

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Chapter 1

Comparing Service Prices among Providers and Tariff Plans

1.1 General introduction and motivation

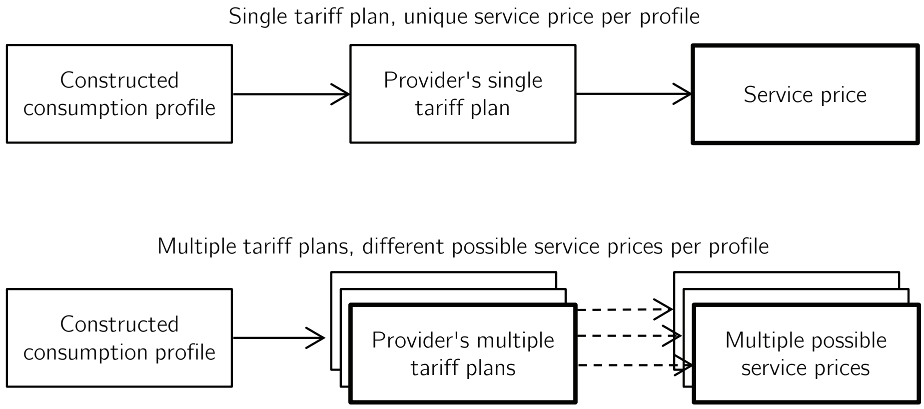
The real income of consumers, and consequently their consumption and wealth, are influenced by prices. Likewise, firms' profits depend on prices. Especially in monopolistic or oligopolistic competition, firms tend to have price-setting power. This is particularly unfavourable for consumers, but is also a problem for the entire allocation. The markets of numerous important services such as, for example, mobile communication or public transport, are not perfectly competitive. For that reason, prices are monitored and compared among service providers by governments, independent regulators and other organisations.

Prices of goods are measured or compared among providers via price indexes. Especially when prices for 'complex' services are analysed, these indexes usually have one issue in common: tariff plans. The tariff plans of the services analysed in this thesis and the resulting issues for price statistics are illustrated below. First and most importantly, if there are different tariff plans, consumers can choose how to pay for a service. This results in different prices for the same service. Consider, for example, fare systems in public transport. A consumer can decide how to pay for a journey. The consumer may pay for one or multiple journeys with a travelcard or single tickets. Depending on the chosen tariff plan, the price paid for each journey is different. A second example is mobile communications services. Multiple providers offer different telecommunication tariffs or contracts to consumers. The price for mobile communication services, which for consumers is the monthly invoiced amount, is not only dependent upon the consumption of multiple units, such as minutes called, text messages sent or data used. The specifications of the selected contract influence the price as well. Prices that result from tariff plans are therefore not only dependent upon the consumption of service units, but also on contract specifications. The third example is prices for basic services, such as water supply, electricity or waste management. In this case, it is not only a few providers, but all municipalities that may offer proper tariff plans, which requires efficient methods for comparing prices. Generally, tariff plans are in use for a large number of services. Their diversity and complexity pose problems for price comparisons.

To compare service prices resulting from tariff plans among providers, independent regulators or organisations such as the Organisation for Economic Co-operation and Development (OECD) currently use methods based on constructed consumption profiles. Usually, a few profiles for different consumption intensities, such as small, medium or large, are defined. In these constructed profiles, quantities for several consumed service units, such as the number of calls or text messages, are specified. Then, the price to be paid for each profile and provider is determined. Thus, service prices for different, standardised consumption intensities are compared among providers. Fixed, standardised profiles are used because observed service prices of different consumers and providers cannot be compared directly. Different quantities of consumed units result in incomparable service prices. Similarly, standard price index formulas, which use quantities and unit prices, can hardly be applied. Implicit unit prices cannot be deducted directly from tariff plans. Normally, only explicit marginal unit prices are directly observable. For example, while the explicit marginal price per additional minute called is indicated in the contract, it is not the implicit unit price paid. The effective or implicit unit price is dependent upon the specifications of the tariff plan (for example, fixed cost or flat rates), as well as the consumption of other units.

The application of consumption profiles to compare service prices among providers poses several problems. First and most importantly, the presence of multiple tariff plans per provider is crucial. As long as one single tariff plan per provider exists, one unique service price per profile and provider can be determined. As soon as a provider offers multiple tariff plans for one service, it is not unambiguously clear which tariff plan should be chosen to determine the service price for a profile. Therefore, several possible service prices per provider and constructed consumption profile exist, as illustrated in figure 1.1. Hypotheses about consumer behaviour must be made in order to select one tariff plan to determine the service price to be compared. In the case of mobile communication prices, for example, the OECD suggests that one should always select the contract that minimises the price per profile and provider. This method implies rational and perfectly informed consumers. It is not clear at all if consumers really possess these optimal contracts for their individual profiles. Price indexes and comparisons should reflect the prices paid in the real world, and not those which are theoretically optimal.

Figure 1.1: The problem of multiple tariff plans per provider



Besides the central issue of multiple tariff plans, comparing service provider prices with consumption profiles poses additional problems. The four major problems are listed below:

- Tariff plans may contain a large number of specifications. Consider, for example, discounts for students or young people on public transport or mobile communication. Consumption profiles usually don't specify the age of consumers. Therefore, the prices actually paid by a large number of consumers cannot be determined accurately by profiles.

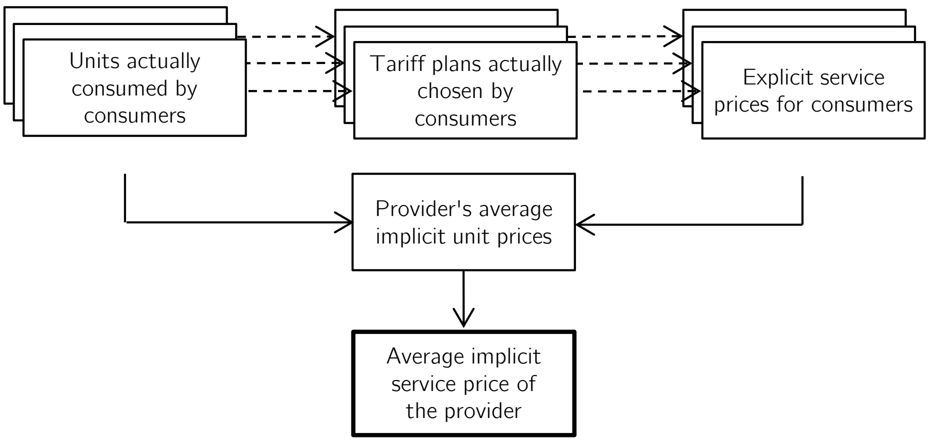
- It is impossible to reflect a complete consumption distribution with only a few profiles. A service may contain different units, such as in mobile communication minutes, text messages or megabytes all of which have to be specified. With, for example, three profiles, only a few specific consumption patterns can be considered.
- As for most other price indexes, adjusting prices to account for service quality is difficult. Again, profiles become too complex and specific if different quality levels are specified.
- Service providers may adapt their tariff plans to the profiles if they are announced in advance and not changed frequently.

For these reasons, using consumption profiles to compare provider prices resulting from tariff plans is not a satisfying approach. Nevertheless, service-specific technical manuals from independent regulators, statistical organisations or offices predominantly suggest the application of profiles; see, for example, OECD (2010) for mobile communication or Federal Electricity Comission (2012) and Price Control (2012) for basic services in municipalities. On the other hand, the general problems for price statistics caused by tariff plans are rarely discussed. Tariff plans have very distinct characteristics across different services, so it is difficult to suggest general solutions. All service prices analysed in this thesis are included in consumer price indexes (CPI) through elementary indexes in the lower levels of aggregation. In the CPI manual of the International Labour Office (2004) - which is one of the major manuals in price statistics - problems related to tariff plans for mobile communication services are identified. Possible solutions, such as using profiles, comparing unit prices or sampling phone bills, are briefly mentioned, but not specified. In the rather theoretical general price statistics literature, tariff plans are not mentioned, e.g. Diewert (2002). The issue is also too specific for statistical text books and therefore not contained, e.g. Fahrmeir et al. (2007). The (scientific) literature research indicates that tariff plans are analysed in other fields, for example, in marketing or microeconomics, with a focus on consumer behaviour. However, as the central issue of this thesis is to measure and compare service prices among different providers, this literature is not described here.

Service-specific literature is introduced in the corresponding chapters.[1]

The contribution of this thesis is to present and apply alternative methods for comparing provider prices that result from tariff plans accurately. The general approach is to evaluate observed service prices with regard to the corresponding consumption. To this end, observed explicit service prices as they are paid by consumers are evaluated according to the units of a service actually consumed. As a result, implicit unit prices are obtained, as illustrated in figure 1.2. When implicit unit prices can be estimated, nearly every statistical method is applicable to weight and aggregate them to obtain an average implicit service price for a provider. Finally, this average implicit service price reflects the average price paid with respect to actual consumption. To sum up, the central difference with the profile method is that it allows evaluating explicit service prices according to actually consumed units, instead of determining hypothetical service prices with the help of constructed consumption profiles and tariff plans.

Figure 1.2: Determining the implicit service price of a provider



At first glance, it may seem that not including tariff plans in the price comparison is a loss of information. However, in the end, there is no need to implement the complex and diverse tariff plans directly. Tariff plans are still incorporated

[1]The literature researches were carried out on `ideas.repec.org`, `webofknowledge.com` and `scholar.google.com` with a wide variety of keywords and the corresponding combinations. General keywords were for example 'price', 'price statistics', 'price index', 'tariff', 'tariff plan', 'tariff scheme', 'price plan', 'price comparison', 'provider', 'service', 'service provider', 'service price' etc.

indirectly in the observed, explicit service prices needed to estimate implicit unit prices. No hypothesis about consumer behaviour is required to select the optimal tariff plan. Because all consumption (or at least an estimation of it), and not only a few constructed profiles, are considered, a provider's average service price can be determined accurately. In addition, there is no utility for providers to adapt tariff plans to the consumption profiles of statistical offices. As a result, the suggested methods allow to compare provider prices much more precisely than with constructed consumption profiles. In contrast with the profile method, all and, more importantly, different tariff plans can be implemented consistently.

This thesis suggests and applies three different methods to compare prices from different providers and tariff plans. They are applied to mobile communication, public transport and basic service prices in Swiss municipalities. All of these services are frequently purchased by most households and therefore have a certain relevance. Firstly, mobile communication services are purchased by most citizens. The tariff plans are complex, especially when analysed as aggregates of providers. Secondly, public transport prices are not only relevant to consumers, but also in politics. The whole infrastructure is dependent upon government subsidies. Hence, prices for consumers are influenced by fiscal decisions. Finally, basic services, like electricity, water supply and waste management, are consumed by all households. Administered prices for basic services are rarely analysed in the literature. For all services mentioned above, markets are not perfectly competitive or even regulated. In the latter case, markets are influenced by politics or governments. Consumers are a weak collective in the political process as stated by Olson (1965). In this light, prices should be monitored even more intensively. The aim of this thesis is to offer alternative and consistent price index concepts to compare services prices among different providers and tariff plans.

1.2 Thesis outline

To address the problems that emerge with the use of consumption profiles, this thesis offers and applies service-specific index concepts. Analysed tariff plans, suggested index concepts and empirical applications for each field are introduced in the second section of the general introduction. They are summarised in table 1.1. For every service, prices are measured and analysed with a particular, independent approach. In chapter 2, hedonic price indexes are introduced for mobile communication services. In chapter 3, a Laspeyres-type price index is suggested to evaluate public transport price development. Chapter 4 contains a profile-based index for basic service prices in Swiss municipalities. The most important findings of each project, the issues to be addressed in further research and general insights are summarised in chapter 5.

The concepts for mobile communication and public transport are new applications based on already existing, but greatly modified index concepts. Contrary to the profile approach, both are able to provide precise and theoretically unbiased estimators for provider prices. Both concepts require very high data quality to perform well. Contrariwise, the profile approach for basic services in municipalities does not. Service prices for specific consumption profiles can more easily be collected. Here, consumption profiles can be applied because for basic services, there is only one tariff plan per municipality and service. The contribution of the last chapter lies in the fact that the prices of multiple services are compared jointly. In addition, the magnitudes of the prices are analysed and partially explained by several relevant municipality characteristics, such as tax rates and rents.

Each chapter is divided into four sections: 1 introduction, 2 index concept, 3 empirical application or analysis and 4 summary. The tariff plans analysed, new price index concepts introduced and the empirical applications of each chapter are summarised below.

Mobile Communication

Tariff plans are offered by communications service providers to consumers in the form of mobile communication contracts. These contracts differ widely. Fixed cost, flat rates, marginal cost, discounts for special groups of consumers or discounts on the price of mobile phones are just some specifications. The OECD method presently used compares minimal cost contracts for fixed consumption profiles among providers. This method is not capable of including most specifications of tariff plans, which results in overly simplified and biased price comparisons.

Table 1.1: Thesis outline

Chapter / Content	Tariff plans	Price index concept	Empirical analysis
2 Mobile Communication	- Service providers' mobile communication contracts -Contracts transform consumed units into invoiced amounts	-Hedonic price indexes (double-imputation, chaining) -Price for average, aggregate consumption	-Price comparison of mobile communications service providers -Data: 415 phone bills from 2012 and 2013 (Swisscom, Orange) -Basic evaluation of model specifications and indexes
3 Public Transport	-Tickets and travelcards of transport companies and tariff unions -Identical trips can be purchased with different tickets	-Laspeyres-type price index -Price development of an averagely travelled kilometer	-Analysis of SBB price development from 2007 to 2011 -Data: Aggregates of kilometers and revenue per ticket type -Comparison to ticket based price indexes
4 Basic Services	-Municipality-specific tariffs for basic services -Electricity, waste management, water supply and sewer water	-Price index based on household consumption profiles -Price level for a representative household	-Service price comparison across the 324 largest Swiss municipalities in 2012 -Data: Service prices for three standard households -Focus on economies of scale, tax rates, rents, institutional control and capitalisation

To address this issue, hedonic price indexes are introduced to adjust prices for consumed services. Hedonic price indexes are generally used to adjust prices for quality, predominantly for housing, but also for technology goods. Here, they are modified to adjust explicit service prices to actually consumed units. The hedonic model is based on data from phone bills, which contain explicit prices (monthly invoiced amounts) and consumed quantities of units, such as minutes called, text messages sent and data used. Monthly invoiced amounts are evaluated according to observed consumption. More precisely, implicit unit prices for minutes, text messages and data are estimated by regressing the invoiced amount on these units. Then, based on the implicit unit prices, invoiced amounts for the average consumption of different providers can be predicted and then be used to compare aggregated service prices. The theoretical section is mainly about how to specify the hedonic function and which index formula best fits this case. The hedonic approach solves nearly all of the problems inherent in the use of consumption profiles. Most importantly, no assumptions about consumer behaviour have to be made. As a result, real-world prices are compared.

In the empirical section, the method is illustrated using data from 415 phone bills. Model specifications are estimated by different methods, and indexes are subsequently constructed. Because the sample contains only phone bills from employees and students of the University of Fribourg, the results are not representative for Switzerland. However, this first application provided a great deal of theoretical and practical insights about hedonic price indexes for mobile communication services. Interestingly, the obtained results contradict the official statistics, according to which Orange is cheaper than Swisscom, especially for small consumption profiles. If this difference is caused by the non-representative sample or, if tariff plan specifications, such as student discounts, do influence implicit unit prices so strongly is an open question for further research. However, it is shown unambiguously that mobile communication prices cannot be measured and compared accurately through a few consumption profiles.

Using hedonic price indexes to compare service prices from tariff plans is a very promising alternative to consumption profiles. Besides the fact that the resulting implicit service prices are adjusted to consumption, a hedonic approach also allows additional analyses of service prices, as demonstrated at the end of the empirical section.

Public Transport

The third chapter is about public transport fares or prices. Consumers can pay for their trips with single tickets, travelcards or a combination of both. The very extreme case is the GA travelcard (Generalabonnement, abonnement général) which is a flat-rate tariff. In this tariff plan, there is no relation between price and consumption. Measures currently used to describe price development in public transport are based on tickets and consequently on tariff plans. Given the importance of public transport in Switzerland, which shows an increasing demand (number of kilometers travelled) and increasing explicit ticket prices, an index that reflects implicit prices is needed.

As a solution, a modified Laspeyres price index is suggested. Kilometers travelled are used as basic goods, instead of tickets or travelcards. Based on revenue and the aggregated kilometers travelled with a specific ticket type, the average price per kilometer travelled can be determined. The resulting index describes the price development of an average travelled kilometer and reflects several important issues, such as increasing consumption.

The data to illustrate this index concept are provided by the Swiss Federal Railways (SBB, CFF). Revenue and kilometers travelled per ticket type are the basic variables. They describe monthly aggregates for the SBB from 2007 to 2011. With this data, the price development of an average SBB-kilometer from 2007 to 2011 is described. Compared to given price indexes, which are based on ticket prices, price increases are estimated to be significantly lower. In years without any tariff changes, the estimated implicit service prices may even fall, which is never indicated by existing indexes, which use the explicit prices of tickets and travelcards.

Basic services in Swiss municipalities

Prices for electricity, water supply, sewer water and waste management services are analysed in the fourth chapter. The prices for these services are administered on a municipal level and differ quite a bit. Two major contributions are proffered through this analysis. First, based on data from the Swiss Price Control and the Federal Electricity Commission, an index that describes prices for multiple services, and not only a single service, is constructed. Although it is based on consumption profiles, thus far it represents the best way to analyse basic service prices in Swiss municipalities. Secondly, an analysis of basic service prices corresponds to the household perspective on user charges and consequently a part of non-tax government revenue. If user charges are analysed in the literature, then they are mostly implemented as aggregates, which does not necessarily reflect the effective burden of households. By analysing service prices as they are paid by households, findings about user charges can be discussed and verified from an alternative perspective.

The indexes for administered prices estimate the total and individual cost for all selected services in a municipality. The cost for a representative Swiss household is approximated by using three different household consumption profiles. Consumption profiles can be used in this case because, for most services, there is only one tariff plan per municipality. The structure of this chapter differs slightly from the others. The empirical results of the indexes have already been presented in the second section, along with the index concept. Service prices from 2012 are analysed descriptively across the 324 largest municipalities in Switzerland. For the identical set of services, the aggregated administered price in the most expensive municipality (Le Locle) is approximately 2.5 times higher than in the least expensive municipality (Lugano).

An attempt to provide economic explanations for service price differences across municipalities is made in the empirical section. In a cross-sectional analysis, the administered price indexes are related to different municipality characteristics like those generally used in public economics. The most robust result is that tax burden and administered prices are related positively across municipalities. Municipalities with high tax rates have typically higher (administered) service price levels. Another, but not highly robust, result is that, in cantons with strong finance commissions, service prices are lower. No evidence is found for capitalisation of service prices in rents. Economies of scale with respect to population and agglomeration size are not present in service prices.

Chapter 2

Hedonic Price Indexes for Mobile Communication Services

In chapter 2, hedonic price indexes are introduced to compare communications service providers. A sample consisting of 415 bills is used to illustrate the indexes.

After an introduction to mobile communication in Switzerland and the presently used method to measure prices in section 2.1, the hedonic model and indexes are created in section 2.2. The method is applied in section 2.3. Section 2.4 consists of a summary, an outlook and a discussion of practical issues.

2.1 Comparing communications service providers

Prices for mobile communication services vary significantly across countries, providers and individual consumers. Providers compete mainly by offering different contracts or tariff plans to consumers. Consumers try to minimise mobile communication cost. They choose a provider and contract accordingly. However, these contracts usually include a large number of specifications that cannot be fully addressed through price comparisons.

Price comparisons between different providers are usually made by independent regulators, statistical offices or private companies. They are even more complex than the comparisons of single tariff plans as done by consumers. Communications service providers offer entire systems of tariff plans, different service qualities and also different levels of customer care. By introducing hedonic price indexes for mobile communication, this analysis provides a convincing and - compared to current price comparisons - more accurate method.

In Switzerland, the Federal Office of Communications is both, regulator and the statistical authority for mobile communication services. The price comparisons of the Federal Office of Communications (2013) base on recommendations of the OECD (2010) to use so-called 'minimal cost consumption profiles'. More concretely, three basic profiles for small, medium and strong consumption are constructed. For all three profiles and for every provider, the monthly minimal cost tariff plan or contract is selected for comparison.[2] Minimal costs are compared because multiple tariff plans per provider exist, and one must be selected for each profile. Therefore, prices are compared as if consumers always used the tariff plan with the lowest cost. If consumers were rational, perfectly informed and completely flexible in their choice of contract, consumption profiles could be applied in this way. However, this is not the case.

First and most importantly, consumers are not necessarily perfectly rational in terms of minimising their communication cost. For example, discounts on phone prices for subscribing a new contract are often more important in their selection of a certain tariff plan than the expected total communication cost. Secondly, the complete information hypothesis is violated because people do not know ex ante their own consumption. Consumption cost is not only dependent upon consumed units, but also upon the specifications of the contract or tariff plan. It is very difficult for consumers to pay attention to all specifications, like flat rates or discounts received for subscribing. The minimal cost approach neither verifies that consumers are well informed by the provider so that they can effectively select the lowest cost tariff plan for their consumption. Thirdly, consumers cannot switch between providers flexibly. A minimal contract duration of one or two years is standard. Additionally, consumers are often faced with rollover contracts, which are automatically extended af-

[2]Minor method changes were implemented in November 2013, which were motivated by new recommendations from the OECD (2012). The major change was the addition of data traffic to the profiles.

ter the basic duration, unless explicitly terminated. Changing contracts with a specific provider is usually possible, but only if a more expensive contract has been chosen. Besides the three principle problems discussed, the Federal Office of Communications has identified other problems with the minimal cost approach:

- All special services such as, for example, roaming packages, cannot be implemented.
- Price discounts on phones that are given for subscribing a contract are not considered.
- Demographic discounts such as, for example, for students, cannot be considered.
- Network quality and coverage are not included.

The method used by the Federal Office of Communications is a simple way to create a price comparison, but it neglects major aspects of mobile communication tariffs. The greatest obstacles to develop the profile approach to an accurate method are the quickly changing, complex and diverse tariff plans. A method that is independent of tariff plans solves most of these problems. This is why hedonic price indexes can significantly improve price comparisons across providers. Hedonic price indexes are usually used to adjust prices to account for quality. They are applied for housing, computers, mobile phones or cars; see, for example, Triplett (2004), Hill (2011), Berndt and Rappaport (2001), Dewenter et al. (2007) or Beer (2007). However, hedonic price indexes are rarely applied for communication services. In the U.S. CPI, hedonic price indexes are used to adjust communication prices to account for improved call quality over time (for example, the clarity of calls), see Fixler et al. (2001). But they are not used to identify quantities consumed and prices paid with tariff plans. In addition, they are not adjusted to compare prices among mobile communications service providers, which yields different problems than an index used to describe the general price development over time. Deligiorgi et al. (2007) used a hedonic approach to identify price-relevant characteristics of ADSL connections in Europe. Finally, the fact that tariff plans pose problems for consumers in their selection of the optimal tariff plan for mobile communication services has been discussed by Xavier (1998) or Miravete (2003). However, none of these articles has focused on price comparisons among mobile communications service providers.

In this project, hedonic price indexes are introduced to compare prices among different mobile communications service providers. They are used to evaluate explicit communication service prices according to actual observed consumption. Different tariff plan specifications from all providers can be implemented identically, and the limits of the consumption profile method are surpassed. All tariff plans can be compared identically, because the index evaluates explicit invoiced amounts according to units actually consumed, which is something every consumer has with every tariff plan.

To construct a hedonic index, first, invoiced amounts are regressed on consumed units. Subsequently, implicit unit prices of the providers can be estimated. Then, these implicit unit prices can be used to compare prices for consumers' actually observed consumption patterns among providers. More precisely, for a given consumption pattern, the hypothetical price (invoiced amount) for all providers can be predicted using the implicit unit prices. As a result, the predicted invoiced amounts compared are adjusted to actually consumed units. These imputed invoiced amounts are finally aggregated or averaged through Fisher or Törnqvist price index formulas to compare the providers. By adapting hedonic price indexes to mobile communication services, most problems discussed above are completely resolved. Only the last point, which has to do with network quality and coverage, is only partially implemented. This method allows the comparison of mobile communication service prices among providers over time with regards to effectively consumed units, different tariff plans and customer service quality.

The hedonic model is presented and specified in the first part of section 2.2. The model is based on information from the bills consumers receive. In the basic hedonic function, the invoiced amount per month is explained by the consumption of units as minutes, text messages, megabytes and the phone received for signing the contract. The hedonic function can be specified in various ways. Therefore, four different specifications are suggested. The second part discusses the index method and formulas used. The double-imputation approach applied favours Fisher and Törnqvist price index formulas. It is mainly the endogenous relation of consumption to tariff plans that has a crucial impact on the choice of the index formulas. To compare multiple providers over multiple time periods, chaining is suggested.

In section 2.3, various estimation methods are applied to the model specifications in order to estimate implicit marginal unit prices. Based on the estimated implicit unit prices, standardised invoiced amounts can be predicted. These are required by the index formulas to compare the service prices of different providers consistently. The hedonic price indexes are used to compare prices of Swisscom and Orange. The data come from monthly bills, except for the mobile phone received for signing a contract. The underlying sample contains 415 bills from 60 consumers between 2012 and 2013.

Finally, an extended conclusion follows in section 2.4. First, the key results are summarised. In the second part, the outlook for further research is discussed. The last subsection addresses practical aspects that have not been included in any other part before, but which are still important in the creation of hedonic price indexes for mobile communication.

2.2 Hedonic price index concept

The hedonic price indexes for mobile communication services are motivated and formally described in this theoretical section. First, in subsection 2.2.1, the newly developed idea for the general model and the resulting hedonic function is introduced. Because this is the first application of hedonic price indexes for mobile communication services, different specifications for the hedonic function are presented in subsection 2.2.2. The model specifications are needed to estimate the implicit unit prices. A well-specified model forms the basis of a hedonic price index and greatly influences its accuracy.

Two index concepts to compare providers are outlined in 2.2.3. Both require implicit unit prices for all providers to be compared. A Fisher index describes price levels from a market or producer perspective. This is complemented by a modified Törnqvist index, which compares prices from a representative consumer's perspective. Again, two concepts are presented because there is no prior literature that has suggested index formulas for mobile communication. In addition, different index formulas yield different interpretations of the price comparisons. Then, the method for simultaneously creating indexes over multiple time periods and providers is illustrated.

Finally, in subsection 2.2.4, the choice of the double-imputation method and the specific index formulas is motivated. Advantages, compared to other hedonic price index types, are outlined. All presented specifications and index formulas are known concepts from the hedonic price index literature. They are usually applied to housing, and so they have been (quite notably) modified for application to mobile communications services.

2.2.1 General approach and the hedonic function

A hedonic price index for mobile communication can be created in various ways. The newly developed approach presented here is meant to model mobile communication service prices as accurately as possible. Basic specifications of the model and, consequently, the hedonic function must be made in the beginning. It seems very reasonable to start with monthly bills as basic observations. A consumer i receives a bill every month from its provider t. It contains the price, or total cost, and the corresponding service units consumed. To keep the notation as simple as possible, t denotes both, provider and corresponding time period of an observation. Because index formulas are used later on, specifying provider and time period separately is not necessary.

The price for communication services p corresponds to the monthly invoiced amount, minus the cost of all services from third companies. Therefore, in the price, only the services of the provider are considered. Other services, like costly hotlines or train ticket purchases via text messages, for example, are excluded from the model. The invoiced amount is dependent on the contract and the consumed service units. The tariff plan, or contract c, transforms vector x, containing all consumed units, into the invoiced amount. For every consumer i and provider t, this relation holds.

$$p_i^t = c_i^t(x_i^t) \tag{2.1}$$

The contract or tariff plan c can therefore be interpreted as a function that transforms the consumed units x into a price p. This is the basic hedonic function. Keep in mind that consumed units are dependent upon the contract of provider t. A consumer with a complete flat-rate tariff plan, for example, such that the invoiced amount is independent of consumption, probably consumes more than he would without a flat rate. If all price-relevant consumption variables are captured by the consumption vector x, the hedonic function (2.1) can be specified and estimated. Therefore, single contracts, and especially their specifications, are no longer directly relevant. The 'average' contract of a provider t can be estimated. The precise model specifications to estimate c are introduced in the following subsection. This subsection is closed by introducing all consumption variables considered price-relevant and thus included in x.

The following consumption units are considered as relevant to the invoiced amount:

- Minutes landline: minutes called on a fix net phone. These minutes can be separated into on-net calls on the fix net of the provider with which consumer i has a contract or off-net calls to a different one.
- Minutes mobile: minutes called on another mobile phone. These minutes can also be separated into on-net and off-net calls.
- Short message services (SMS): number of SMS sent.
- Multimedia message services (MMS): number of MMS sent.
- Megabytes (MB): number of mobile data traffic consumed, measured in MB.
- Roaming to other countries: all units, apart from MB and on-net calls, can be made to another country and bring about special roaming tariffs. These units are usually more expensive for the consumer in the end.
- Roaming abroad: if one of the units above is consumed abroad, special tariffs are used, depending on country, involved providers and international regulations. Calls received abroad are also included.
- Discount on the phone price: for signing a contract, providers sell mobile phones with a discount. The longer in duration and the more expensive the signed contract, the higher the discount. The discount is divided by the minimal duration of the contract in months to obtain the discount per month. More precise descriptions follow in the data subsection 2.3.1.

Another variable that might be considered is the number of calls. All minutes are included as aggregates per month. This method does not completely describe the consumption, because for a given amount of minutes, the number of calls varies. The more connections established, the higher the cost for a given number of minutes consumed. Note that all variables observed appear on most bills. Only the information about the discount on the mobile phone price given for signing a contract does not. This additional information was gathered through a consumer survey. The discount is price-relevant consumption, and so it must be included. It is also very important for the choice of contract, which is often motivated by the phone and thus, the discount. The magnitude of the discount is usually indicative of the size of the fixed cost of a contract, which is the second-most important factor in consumers' choice.

That consumption can be influenced by the contract becomes a problem for the estimations. For this analysis, it is assumed (for econometric reasons) that the choice of the contract is dependent upon the fixed cost and is thus captured in the discount on the phone price. Consequently, all other consumption variables are assumed to be independent of the contract. Obviously, this assumption and its implications can and should be discussed in further applications.

Finally, consumption not only contains explicitly billed units and quantities; it is also a question of quality. Both geographical network coverage and the speed of the data connection are crucial aspects. They are partially included in the model, but only as cap for maximal consumption. The basic logic is that with increasing network quality, potential consumption also increases. For example, in a high-quality network, a consumer can have a lot of data traffic in a month, whereas in a low-quality network, it is physically not possible. As long as consumers in a good network have relatively high data traffic and those in low-quality networks have small traffic, the hedonic approach can capture the quality via the quantity consumed. However, if, for example, a consumer likes a fast data connection but only uses a few megabytes, or vice versa, a consumer has a weak connection but uses it continuously, the assumption is violated. Precisely how the quality of a network should be included is not discussed here. It is assumed that the quality of the networks is at least partially indicated by the amount of units consumed.

2.2.2 Model specifications for the hedonic function

After introducing the basic approach, specifications for the hedonic function in equation (2.1) are presented. Four specifications are suggested, namely the linear, a decreasing marginal price, a semi-log and a Box-Cox specification. For a precise discussion of these specification forms in the context of housing, see Yu and Prud'homme (2010) or, more generally, Cropper et al. (1988). Because mobile communication services have yet to be measured by hedonic price indexes and differ greatly from houses, four specifications are considered to start with. These are then evaluated in the empirical section 2.3. Again, the specifications are important because they contribute an essential part of the quality of the estimated implicit unit prices, the predicted or imputed prices and, consequently, the price indexes.

Contrary to hedonic price indexes for houses or cars, the individual functions that transform consumption variables into a price are known precisely through the underlying contracts. At first glance, this might be a very strong indicator for the specification of the hedonic function. The hidden aspect of the problem is that these tariff plans are extremely varied. For example, a prepaid contract can be a fully linear function of consumption, where every minute, text message or megabyte consumed is paid exactly per unit, with a constant marginal price. On the other extreme, a full flat-rate tariff plan, the invoiced amount is completely independent of consumption, and the function would contain merely a constant. However, in between these two extremes, there is a wide variety of tariff plans. In the data, there is no pure form of both extreme tariff plans. Tariff plans usually contain flat-rate elements to a certain extent, often depending on the monthly fixed cost and demographic discounts. Most flat-rate elements can be observed in data traffic. In contrast, roaming is rarely covered by flat rates.

Besides the tariff plans, customer consultation to offer the client the optimal contract is also relevant. A provider can offer very attractive tariff plans, but if, for example, a lot of consumers with little consumption are in contracts with a high fixed cost, they pay relatively more than they would in contracts with a smaller fixed cost. This highlights the fact that, in the end, optimal model specifications are no longer that easily identified. By relating the invoiced amount directly to consumed units, customer consulting is also included in the evaluation of prices. The uncertainty about the optimal form generated by the variation in tariff plans and customer consulting is the main reason that several model specifications are tested in this analysis.

Linear

First, the linear specification in equation (2.2) is introduced. A linear model is usually used if no further information for specification is available. The wide variety of tariff plans and customer consulting, therefore, supports the usage of a linear model. Prices or invoiced amounts p are modelled as a linear function of all k units consumed by consumer i with a specific provider t. The coefficients β_j can be interpreted as the marginal implicit price of unit j. The constant corresponds to the basic price of signing a contract with a certain provider t. The equation is complemented by the stochastic error term u.

An increase of 1 in the consumption of unit j raises the invoiced amount or price by its marginal implicit unit price β_j. Note that consumption x is in this subsection described for a single good j, and not as a vector of all goods, as it was before and will be later in the definition of indexes. Describing specifications is more convenient with single units, whereas the hedonic function and the indexes can be better described with using vectors.

$$p_i^t = \beta_0^t + \sum_{j=1}^{k} \beta_j^t x_{ij}^t + u_i^t \tag{2.2}$$

The linear model's key benefit is that the levels of the estimated coefficients can be interpreted as constant marginal unit prices. This helps to validate the estimated coefficients. If the constant was suppressed, the coefficients could be interpreted as average unit prices. However, they would be biased. Estimations of specifications without a constant, which offer interesting insights about the magnitudes of unit prices, are reported in appendix A.1.1.

Note that the marginal unit price in the linear specification for the first megabyte is the same as for the thousandth, for example. It seems reasonable to differentiate this problem.

Decreasing marginal price

By discounting the consumption of unit j by $0 < \theta_j \leq 1$, a decreasing marginal unit price is introduced in equation (2.3). This specification is mainly motivated by the general form of tariff systems. Consumers with low consumption usually have a small fixed cost component and pay a relatively high marginal price per unit. Consumers with high consumption have more flat-rate elements in their contracts, and therefore have a higher fixed-cost component and a relatively lower marginal price per additional unit consumed. By discounting consumption, the predictive power can be increased.

$$p_i^t = \beta_0^t + \sum_{j=1}^{k} \beta_j^t (x_{ij}^t)^{\theta_j} + u_i^t \tag{2.3}$$

This model approach can also be interpreted in other ways. Obviously, the contribution of an additionally consumed unit to the invoiced amount decreases over all tariff plans. All providers diversify their tariff plans such that the higher the consumption, the lower the price per unit consumed. Nonetheless, it can also be seen as a way of decreasing the marginal utility of an additionally consumed unit. The most important megabyte consumed, for example, is probably worth much more than the thousandth. Maybe with the most important megabyte, a very important email is received, whereas with the thousandth, some additional seconds TV stream are consumed.

The interpretation of specification (2.3) is versatile. However, in this first application, the interpretation of the decreasing marginal contribution of a unit to the invoiced amount is used. Mixing utility and hedonic price functions imposes a new framework, as discussed to some extent by Rosen (1974). As this is a first encounter with hedonic price indexes for mobile communication, utility functions are not used in any form.

After introducing two models that are mainly motivated by 'economic' concerns, the following two models are motivated by 'econometric' benefits, possibly offering better prediction quality.

Semi-logarithmic

The semi-logarithmic specification in equation (2.4) linearises the dependent variable. This is motivated by the usual distribution of prices to obtain normally distributed residuals. The coefficients can be interpreted as the semi-elasticity of the invoiced amount. If consumption of unit j is increased by 1, the invoiced amount p changes by $100 \cdot \beta_j\%$.

$$log(p_i^t) = \beta_0^t + \sum_{j=1}^{k} \beta_j^t x_{ij}^t + u_i^t \tag{2.4}$$

Note that a log-linear model (which also takes the logarithm of explanatory variables) is not a useful approach in the mobile communication context. A lot of consumption unit values are equal to 0, and its logarithm would be not defined. Roaming units in particular are consumed erratically.

Box-Cox

The Box-Cox specification in equation (2.5) completes the set. The form is dependent on the parameter λ, which can be estimated by maximum-likelihood. If λ is not significantly different from 0, the semi-logarithmic model specification is used. If it is, then the dependent variable is transformed as described in equation (2.6). The main benefit of a Box-Cox specification is that usually the residual distribution is closer to a normal distribution.

$$p_i^{t(\lambda)} = \beta_0^t + \sum_{j=1}^{k} \beta_j^t x_{ij}^t + u_i^t \tag{2.5}$$

$$p_i^{t(\lambda)} = \begin{cases} \frac{p^\lambda - 1}{\lambda} & \text{if } \lambda \neq 0 \\ log(p) & \text{if } \lambda = 0 \end{cases} \tag{2.6}$$

The four specifications will be estimated in the empirical section. The trade-off is between a simple model specification (linear) with a straight interpretation of results, versus having better specified models that suffice to the most important assumptions of the ordinary least squares estimation (OLS). The goal for hedonic price indexes is generally to have a model with optimal predictive power. However, as this is the first application, other aspects of the model specifications (residual distribution, heteroscedasticity, specification) are also analysed in the empirical section. Other functional forms, especially non-linear models, may also be reliable. Additionally, prices could be predicted by non-parametric methods, such as classification algorithms, but these are not discussed here.

2.2.3 Hedonic price indexes

When the model specifications from the previous subsection are estimated, then the resulting coefficients can generally be interpreted as implicit marginal unit prices. Based on these implicit marginal unit prices, the indexes can be constructed.

In the first part of this subsection, a Fisher index, which describes the price development for aggregate consumption, is introduced. Then, in the second part, a modified Törnqvist index, which measures the price for a representative consumer, is illustrated. Both indexes allow the comparison of the service prices exclusively between two providers. Therefore, in the final part, an approach for comparing multiple providers over multiple time periods through chaining is presented. In the applied double-imputed indexes, predicted prices are used within standard price index formulas. The price predictions are based on the model specifications from the previous subsection. The motivation for the selection of the double-imputation method and the chaining follows in subsection 2.2.4.

Fisher: aggregate consumption perspective

The Fisher price index $P^F_{0,1}$ in equation (2.7) describes the relative price between two providers $t = 0, 1$ for the total amount of units consumed. The Fisher price index is the geometric mean between a Laspeyres $P^L_{0,1}$ and Paasche $P^P_{0,1}$ index. The notation follows Hill (2011).

$$P^F_{0,1} = \sqrt{P^L_{0,1} \cdot P^P_{0,1}} \tag{2.7}$$

Price indexes are growth factors for price levels; thus, the geometric mean is used. The Laspeyres price index, as one element of the Fisher index, is defined in equation (2.8). This index measures how much the total amount of consumed units with provider 0, $\sum_{i=1}^{n_0} x_i^0$, would cost relative to provider 1. It contains all n_0 observed consumption vectors belonging to provider 0. Remember that x_i^t are again vectors of all consumed units of one consumer i of provider t. Based on the model specifications described in subsection 2.2.2, unit prices for every provider can be estimated. By using the double-imputation method, (hypothetical) invoiced amounts are then predicted for all consumption vectors of provider 0 and denoted as $\widehat{p}_i^t(x_i^0)$. Finally, the price or total cost for the aggregated consumption is compared between both providers.

$$P_{0,1}^L = \frac{\sum_{i=1}^{n_0} \widehat{p}_i^1(x_i^0)}{\sum_{i=1}^{n_0} \widehat{p}_i^0(x_i^0)} \tag{2.8}$$

Due to the double-imputation method, the effectively observed prices p_i^0 of provider 0 are not used. To compare both providers equally, predicted prices $\widehat{p}_i^0(x_i^0)$ replace the actual observed prices. Note that the index is implicitly weighted by expenditure shares. A large consumption vector generally results in a larger predicted price and has subsequently more impact on the aggregate than a small one.

The Paasche index (2.9) measures how much the total amount of consumed units of provider 1, $\sum_{i=1}^{n_1}(x_i^1)$, would cost relative to provider 0. Again, due to the double-imputation, it is not the observed prices p_i^1 that are used, but the predicted ones.

$$P_{0,1}^P = \frac{\sum_{i=1}^{n_1} \widehat{p}_i^1(x_i^1)}{\sum_{i=1}^{n_1} \widehat{p}_i^0(x_i^1)} \tag{2.9}$$

The Fisher index, as geometric mean of Laspeyres and Paasche, describes the price change of aggregated consumption between two providers. Aggregated consumption and estimated unit prices of both providers are equally included. If only a Laspeyres or Paasche index were used, then the consumption of only one provider would be used as weights for the predicted prices. Even more important is the fact that consumers adapt their consumption to tariff plans or contracts. If, for example, only the consumption vectors of provider 0 were used, the predicted prices for provider 1 would become relatively high. Consumers of provider 1 adapt their consumption to the tariff plans of provider 1 to minimise communication cost. If the tariff plans or contracts are different between the two providers, a non-symmetric index would result in a significant bias. Using symmetric indexes is essential for comparing communications service providers. Additionally, the number of observations is allowed to differ across providers and periods, which is a nice property to work with.

Modified Törnqvist: average consumer perspective

The Fisher index compares price levels for aggregated consumption. As discussed, expenditure shares are used. Consumers with high consumption have more weight in the index. This can be a problem because the provider with better tariff plans for intense consumption benefits. Therefore, an index that describes the average price level change for a representative consumer serves as an alternative. Here, all observations obtain equal weights, compared to the expenditure share weights used before.

Like the Fisher index, the Törnqvist index $P^T_{0,1}$ is a geometric mean. But unlike Fisher, it is the mean of the geometric Laspeyres $P^{GL}_{0,1}$ and geometric Paasche $P^{GP}_{0,1}$ indexes, as formulated below in equation (2.10).

$$P^T_{0,1} = \sqrt{P^{GL}_{0,1} \cdot P^{GP}_{0,1}} \tag{2.10}$$

Like in Fisher, both providers are treated equally. The geometric Laspeyres index (2.11) is the geometric mean of the growth factors of all predicted prices for consumption of provider 0. In the standard geometric Laspeyres index, the growth factors are weighted by expenditure shares. But in order to show the price development for a representative consumer, here every observation obtains equal weight. All n_0 observations are weighted equally by $1/n_0$. Therefore, no matter how great the consumption is, price changes for every observation are included with the same weight. As in the basic Laspeyres index, the price development of the consumption of provider 0 is described.

$$P_{0,1}^{GL} = \prod_{i=1}^{n_0} \left(\frac{\widehat{p}_i^1(x_i^0)}{\widehat{p}_i^0(x_i^0)} \right)^{\frac{1}{n_0}} \tag{2.11}$$

The geometric Paasche index (2.12) is also an average growth factor, but for the prices of the consumption with provider 1. All growth factors of all observations obtain again equal weights $1/n_1$. Note that double-imputation is again applied. Observed prices p_i^t are used neither in the geometric Laypeyres nor in the geometric Paasche index. Instead, they are replaced by the predicted prices $\widehat{p}_i^t(x_i^t)$ in order to compare both providers in exactly the same manner.

$$P_{0,1}^{GP} = \prod_{i=1}^{n_1} \left(\frac{\widehat{p}_i^1(x_i^1)}{\widehat{p}_i^0(x_i^1)} \right)^{\frac{1}{n_1}} \tag{2.12}$$

The equal weights used here in the geometric Paasche, Laypeyres and subsequently Törngvist index, could technically also be used in the Fisher index. But the intention when applying the Fisher index is to measure the price of the aggregated consumption. The modified Törnqvist index, in contrast, is an average growth factor in which every observation, regardless of high or low consumption, is included with equal weight. It describes the average price development of a representative consumer. Both indexes describe the price levels in a very similar manner. However, the resulting differences are significant, as shown in the empirical part on indexes in subsection 2.3.3.

Note that it does not matter if the number of observations differs across providers. Both indexes are symmetric and weight the consumption equally for both providers. Nevertheless, the number of observations remains important for the prediction quality. A large difference in the number of observations may result in different prediction accuracies.

Chaining: multiple time periods and providers

The indexes presented in both previous parts describe the relative price level between two providers. In the Fisher approach, the price for aggregated consumption is described, while in the Törnqvist index, it is the price change for an average consumer. An index for mobile communication service prices should be able to describe prices over multiple providers and time periods.

The focus of the method presented here lies in stability. Indexes should not change ex post; they should describe prices of period- or provider-specific consumption as precisely as possible and be flexible in terms of modification. This can be achieved by chaining indexes over time, as illustrated with the example below.

Consider as initial position three time periods $s = a, b, c$. The underlying market contains three providers $t = 1, 2, 3$, where $t = 0$ denotes the complete market, including all providers by their market shares. All providers are compared to the entire market (base) within one period. There is no need to introduce a market index, and any provider might be used as base. But if every provider should be treated equally, a market index seems a fair tool for avoiding the over-representation of one provider.

The chaining method applied to obtain indexes across all providers and time periods can be described as follows:

1. In every single period s, price indexes for the complete market 0 and every single provider t are created. As base period serves the complete market 0. The period s-specific indexes $P_{s0,st}$ are independent between different time periods.

Table 2.1: Indexes with base period t

	0	1	2	3
a	100	$P_{a0,a1}$	$P_{a0,a2}$	$P_{a0,a3}$
b	100	$P_{b0,b1}$	$P_{b0,b2}$	$P_{b0,b3}$
c	100	$P_{c0,c1}$	$P_{c0,c2}$	$P_{c0,c3}$

2. Indexes between markets for all subsequent periods $P_{s0,(s+1)0}$ are created. In this three period example, two indexes result: $P_{a0,b0}$ and $P_{b0,c0}$.

3. All market indexes are chained through simple multiplication. With three periods, only one index has to be chained.

$$P_{a0,c0} = P_{a0,b0} \cdot P_{b0,c0} \tag{2.13}$$

As a result, all market indexes have the desired base period $a0$.

4. Finally, all index bases need to be changed to $a0$. Provider indexes are chained with the new market indexes with base period $a0$ and corresponding reference period $s0$.

$$P_{a0,st} = P_{a0,s0} \cdot P_{s0,st} \tag{2.14}$$

Thus, all indexes have base period $a0$. Note that the resulting representation in table 2.2 corresponds to the OECD approach for inter-periodical comparisons. For intra-periodical price comparisons, each period's market serves as base period, as illustrated in table 2.1.

Table 2.2: Indexes with base period 0

	0	1	2	3
a	100	$P_{a0,a1}$	$P_{a0,a2}$	$P_{a0,a3}$
b	$P_{a0,b0}$	$P_{a0,b1}$	$P_{a0,b2}$	$P_{a0,b3}$
c	$P_{a0,c0}$	$P_{a0,c1}$	$P_{a0,c2}$	$P_{a0,c3}$

An ex post change of base period $a0$ to a period $\tau 0$ can be done by a base change, see equation (2.15). After the base change, the index value of the new base period corresponds to 100 points (by definition).

$$P_{\tau 0,st} = \frac{P_{a0,st}}{P_{a0,\tau 0}} \tag{2.15}$$

Theoretically, all indexes could be calculated directly for the desired provider and period. Remember that in both index concepts, Fisher and Törnqvist, the consumption of the base and reference periods are included symmetrically. As long as the base and reference periods show similar consumption patterns, the resulting difference between chaining or directly determining indexes with desired periods should not be large.

However, as soon as the base and reference periods are further away, technical progress and new tariff plans change consumption significantly. In the more recent period, new goods or units that did not exist in the older period might be consumed. Solutions to these problems - like ignoring new goods - are given, but the final result is always inferior. Chaining allows for the description of changes in consumption better than directly computing indexes. If new goods or units are introduced in a period, they can be implemented in the subsequent period without any technical issues.

2.2.4 Comments on the indexes

To compare provider prices, double-imputed Fisher and Törnqvist indexes are suggested. To create indexes over time and multiple providers, chaining is applied. In this subsection, the choice of the double-imputation method, the two index formulas and the chaining is motivated. These comments are not needed to understand the index concept. They are simply meant to motivate these choices with respect to other possibilities within the hedonic framework.

With the double-imputation method, standard price index formulas with predicted prices are used. Theoretically, it would suffice to use hypothetical predicted prices for one provider and compare them to the truly observed prices of the other provider. This would be the (single-)imputation method. With the single-imputation method, providers are not treated in the same manner. Perhaps the model used has a hidden bias, missing variables or something else that systematically influences the index. While comparing tariff plans belonging to two providers, one provider could be systematically favoured, which is generally not regarded as desirable. Comparing the service prices of both providers in an equal manner is preferable.

The symmetric index formulas of Fisher and Törnqvist are used. The Fisher index describes a provider's price development for aggregated consumption. The modified Törnqvist index describes an average consumer's price development. Both are so-called superlative price indexes, see for details the consumer price index manual of the International Labour Office (2004). They treat both providers (which are compared) in an equal or symmetric manner. Remember that consumption is dependent on tariff plans. If symmetric indexes are not used, the provider who serves as the base (in the formulas provider 0) would most certainly be favoured. Consumers adapt to tariff plans, and if the consumption vectors of only one provider are used to predict prices, the predicted prices of the other provider will be relatively high.

Due to the great diversity in tariff plans across time and providers, as well as the rapid technical progress that alters consumption behavior very quickly, chaining is used. More precisely, the indexes are constructed across providers in a given time period. Over multiple periods, the indexes are chained, which corresponds to the multiplication of growth factors. Even though symmetric indexes are used, which would implement consumption and prices in both periods equally, consumption profiles differ greatly over large time intervals. Chained indexes over multiple time periods describe price development for time period-specific consumption - plus or minus one period. Consequently, the index values are not influenced by periods that are far away. Chaining is used in nearly every official price index, mainly to obtain a realistic basket of goods, as well as avoiding problems with new goods that did not exist during the base period.

Finally, besides the imputation method, the time dummy and the characteristics method are popular for hedonic price indexes, see Hill (2011). The time dummy method adds to the model specification a dummy for every period or provider to estimate the relative price. Thus, no index formulas are used, and the price change is indicated by the dummy (which is similar to a fixed effect). Alternatively, the so-called characteristics method could be applied. As with the other methods, a model specification is estimated. Then, based on this estimation, prices are predicted for a few (for example, three) predefined or constructed consumption profiles for every provider and then compared. In the end, two reasons are important to the choice of the double-imputation method. Firstly, index values do not change ex post by adding new time periods, as they do with the time dummy method. For official statistics, it would be very disadvantageous if index values changed with every period added. Secondly, actual observed consumption is used to predict and aggregate prices, unlike in the characteristics method, which uses a few artificial profiles.

2.3 Empirical applications

The empirical section is divided into four parts. In subsection 2.3.1, the data are described. Then, models are estimated in 2.3.2, followed by an illustration of indexes in 2.3.3. The section is closed by an analysis of the impact of the consumers' age on the invoiced amount and, consequently, the indexes in 2.3.4.

2.3.1 Data

The data used are based on a sample of phone bills from students and employees of the University of Fribourg. Compared to a large and representative sample for Switzerland, it is not an optimal solution. Nonetheless, as the goal of this project is to test whether hedonic indexes are applicable to mobile communication, the sample suffices for all basic requirements.

One might even argue that students are better informed than older people and more likely to choose optimal tariff plans. Despite the fact that students benefit from special discounts on their contracts, they usually have a relatively constrained budget, which drives them to minimise mobile communication cost. Moreover, younger consumers usually have fewer problems comparing tariff plans because of their superior technical knowledge. Thus, this sample can be considered as very conservative, containing only well-informed consumers who have relatively optimal tariff plans given their corresponding consumption.

The following description of the data is split into three parts. Firstly, the distribution of sampled bills over time and providers is presented. Secondly, the data sampled from monthly bills are described. Finally, the data from the consumer survey are presented.

Number of observations per provider and quarterly period

The Swiss market for mobile communication is mainly shared by three providers, with Swisscom as the biggest, followed by Sunrise and Orange. There are other providers, but they have very small market shares. Nearly all 415 bills sampled are from Swisscom or Orange. The reasons for this are discussed below.

Swisscom is by far the largest provider. Sunrise bills were supplied very rarely. In Fribourg, where most bills were sampled, Swisscom and Orange have large, centrally located shops, whereas the Sunrise shop is smaller and less central. Additionally, some Sunrise bills did not contain all of the required information about consumed units, and unlike with Swisscom, it was not possible to obtain the missing data via an online customer account. However, contracts from

Sunrise are perhaps not as attractive for students, and that could be the reason for the low number of bills obtained from this provider.

The sample consists of 415 bills from 60 different consumers. The bills are not sampled randomly. The incentive set to encourage people to supply bills was a chance to win a voucher for a new smartphone.[3] The resulting sample is therefore neither entirely representative of the entire Swiss market nor of the University of Fribourg. Additionally, the observations are not independent because one person could supply multiple bills. Every supplied bill was, if possible, included in the sample. The aim of this empirical section is to illustrate how a hedonic price index for mobile communication can be constructed and to test the method. Therefore, all interpretations of empirical results are therefore only valid for the given sample. For a representative price comparison, the observations should be drawn randomly. How to obtain a representative random sample is discussed in subsection 2.4.3.

Table 2.3 shows the distribution of bills over providers and quarters. Orange customers could access bills online for the past year, whereas Swisscom clients only get access to the bills from the previous six months.

Table 2.3: Number of observations per quarter and provider

	Q1.12	Q2.12	Q3.12	Q4.12	Q1.13
Swisscom	0	1	66	99	50
Orange	35	44	43	49	23
Sunrise	0	0	0	3	2
Total	35	45	109	151	75

A few Swisscom bills are for two months. In these cases, the bills (invoiced amount and consumed units) were distributed equally over the two corresponding months. This is not a very elegant solution, and it causes additional econometric issues. However, it is done in order to include only monthly consumption vectors in the data.

[3] Because most consumers already own a smartphone, and receive a new one for signing a new contract, this is considered to be a minor issue. Most people were intrinsically motivated to participate.

Bills

As already mentioned, the sample consists of 415 bills which were supplied by 60 consumers. All bills contain invoiced amount and aggregated consumed units per month. Table 2.4 summarises the data from these bills; only the discount on the phone purchased is not shown on the bills. It is in this table because it includes all of the variables needed to create the hedonic indexes. How exactly the discount is calculated is described in detail at the end of this data description.

The groups that will be used in the grouped model estimation are in the first column. The second and third columns contain single variable names (for single variable estimation), as well as brief descriptions. For all variables, except the phone discount, the arithmetic mean is larger than the median. This indicates outliers in the intense consumption segments. A majority of consumers show a relatively moderate consumption. While in the groups minutes, text messages and MB (megabyte), and therefore in communication in Switzerland, quite high maximum values can be observed, all maximums of roaming groups are much smaller. This is mainly because in a lot of contracts, flat rates apply to national communication, but not internationally. The only exception is calls from Switzerland to abroad (CH minutes roaming), which has a very high maximum. The extremely high values come from one consumer with a flat rate for international communication. As the small median and mean indicate, these extreme values represent outliers.

Three data adjustments to the genuine bills are made:

- The invoiced amount variable used for the model estimation does not correspond exactly to the amount invoiced on the bill. All services from third-party providers, like train ticket SMS, mobile TV, etc., are deducted. Therefore, only the amount invoiced for effective mobile communication through the specific provider is contained.
- In the bills, Swisscom splits landline calls (minutes) into two types. One type consists of calls to another customer with a Swisscom fix net, and the other consists of calls to the fix net of a third-party provider. Orange and most other providers in Switzerland do not have their own fix net phone products. Therefore, these two distinct Swisscom types

Table 2.4: Bills data

Grouped	Single	Description	Mean	Median	SD	Min	Max
Invoiced amount	Invoiced amount	Exclusively for mobile communication services, in CHF	55.61	45.64	33.05	1.10	264.20
Minutes	fix net	Calls on fix net	36.94	16.48	52.69	0.00	343.50
	mobile on	Calls on the mobile net of the provider	84.90	41.90	121.51	0.00	555.90
	mobile off	Calls on mobile nets of other providers	20.44	5.09	31.92	0.00	225.30
Text messages	SMS	SMS sent	50.30	41.00	88.68	0.00	658.00
	MMS	MMS sent	1.55	0.00	4.38	0.00	35.50
MB	MB	Megabyte used	442.50	234.50	663.66	0.00	5954.00
Roaming minutes	CH min. roaming	Calls out of Switzerland	5.55	0.00	53.10	0.00	583.50
	Roaming minutes	Outgoing and incoming calls abroad	1.15	0.00	4.11	0.00	34.05
Roaming text	CH SMS roaming	SMS out of Switzerland	2.65	0.00	8.14	0.00	103.00
	Roaming SMS	Roaming, SMS abroad	2.31	0.00	8.25	0.00	94.00
	Roaming MMS	Roaming, MMS abroad	0.02	0.00	0.16	0.00	2.00
Roaming MB	Roaming MB	Roaming, MB abroad	1.00	0.00	6.88	0.00	95.98
Phone discount	Phone discount	Monthly discount on mobile phone price, in CHF	13.45	14.58	9.64	0.00	38.55

Note: All data described in this table are from the 415 sampled phone bills. Only the discount on the phone cannot be determined by information contained on phone bills. Because it is also required in the hedonic model, it is reported in this table.

are merged into one category for calls on fix net.

- Providers usually round up prices for calls to the next minute; for example a call of 3 minutes and 26 seconds is billed as 4-minute call. On the bill, it is still reported as 3:26-minute call. However, Orange also rounds up the reported minutes and not only the invoiced amount for minutes, so no information about the 'true' aggregated number of minutes called is available. Based on Swisscom bills, which have more precise information, the relation between aggregated, precisely consumed minutes (*Min precise*) per month and aggregated, hypothetically rounded up minutes (*Min rounded*) is estimated. A simple linear regression without a constant (2.16) is employed.

$$Min\ precise_i = \theta \cdot Min\ rounded_i + u_i \tag{2.16}$$

The resulting estimate, $\hat{\theta} = 0.788$, is used as as discount factor for all Orange minutes in order to approximate the 'true' or precise amount of minutes called. An estimation with a constant would be unbiased, but it would lead to negative amounts of minutes and subsequently sometimes to negative predicted invoiced amounts.

How differently scaled consumption units among providers influence symmetric price indexes is not clear, and this is an open question for further research. Nonetheless, for this analysis, I corrected the minutes because having well-scaled units seems very important in the evaluation of the estimations and indexes. The downside of correcting is that it results in a kind of two-stage estimation, which requires special attention. An alternative would be to not correct the minutes and to evaluate them as they are billed. But this would probably lead to a bias in the index.

A last important decision in the data preparation is how variables or units will be divided. In this project, a differentiation is suggested through the use of single and grouped variables. However, the roaming variables in particular could be split more precisely. Incoming and outgoing calls could be separated. Also, a more precise partition of different country groups (Europe, Asia, etc.) could be made. How the partitions should look depends upon the sample size because roaming units are rarely consumed. If only a few or even just one observation containing a specific unit is present, extreme and unrealistic magnitudes of estimated coefficients can sometimes be observed.

Consumer survey and phone discount

Each of the 415 bills is supplied by one of 60 consumers. All participants also supplied information about their contract, phone, data usage and the consumer via a survey, the results of which are summarised in table 2.5. The main reason not to sample only phone bills was that there was no information available on the bills about the phone discount they had received for signing.

The variables needed to estimate the monthly discount are the duration of the contract (Abo duration), the discounted price paid for the phone (Phone price) and the date of purchase (Phone month). The phone discount is normally dependent upon the duration and the monthly fixed cost of the contract. The higher the monthly fixed cost and the longer the duration of the contract, the bigger the discount on the mobile phone price.

The monthly discount (2.17) on the phone price is calculated by subtracting the price of the phone paid to the provider ($Phone\ price$) from the average market price at purchase date ($Phone\ market\ price$) for every observation i. Finally, due to the monthly periods, this difference is divided by the minimum duration of the contract in months ($Abo\ duration$). The market price data were gathered from `www.toppreise.ch`. This represents the average price of a specific phone based on a set of online offers.

$$Phone\ discount_i = \frac{Phone\ market\ price_i - Phone\ price_i}{Abo\ duration_i} \tag{2.17}$$

There are several important things to remark about the discount on phones.

- Some phones are developed continuously, and new specifications (with the same name) enter the market with an elevated price. They can hardly be distinguished from older specifications by description alone. In this context, it would be advantageous to only consider consumers who just signed a new contract.
- Additionally, phones that were purchased more than a year ago might

Table 2.5: Consumption behaviour and phone data

Group	Variable name	Description	Values
Contract	Provider	Provider which with the contract was signed	Orange, Sunrise, Swisscom
	Contract	Name of contract	
	Abo duration	Minimum duration of contract in months	0, 12, 24
	Abo extension	Dummy for contract extension not elected	
Phone	Phone month	Month when signed contract	
	Phone model	Type of phone received	HTC One, iPhone 3 GS, ...
	Phone price	Price paid for phone (with discount)	
	Phone precision	Estimation precision of the phone price	not precise, ..., very precise
	Phone current price	Market price of phone in a given month	
	Phone market price	Market price of phone when purchased	
	Phone OS	Operating system of the phone	Android, iOS, ...
Data usage	SMS	Usage of apps for SMS	
	Min	Usage of apps for calls	0: never
	Web	Usage of apps for surfing	1: unfrequently
	Video	Usage of apps for videos and streams	2: monthly
	Calendar	Usage of apps for calendar	3: weekly
	Mail	Usage of apps for mails	4: daily
	Maps	Usage of apps for maps	5: daily, 5 times +
	Storage	Usage of apps for data storage	
Demographic	Semester	Semester studying or not studying	
	Major	Major subject	
	Age	Age in years	
	Sex	Gender	
	Fix net	Dummy for landline phone at home	

Note: This table contains all of the information gathered via consumer surveys. Not all data will be used in this thesis. Mostly information about contract duration, phone type, phone price and purchase date are used to estimate the discounts on phone prices. The current and market prices for phones are not from consumer surveys, but from `www.toppreise.ch`. Both are needed to estimate the discount on phone prices.

not even be on the market anymore, so no market price is given on www.toppreise.ch. In this case, average market prices were approximated by the prices of phones with similar specifications.

- Alternatively, instead of the market price at the purchase date, the market price in every given month could be used. This is mainly because the customer pays back a part of his (already relatively old) phone, which has a lower current price every month. In the following estimations, only market prices at purchase date are used.
- In table 2.4, the minimal discount is zero. In a first estimation, negative discounts were obtained for one consumer. He indicated (through the variable phone precision) that his estimate of the phone price paid was not reliable. Therefore, this estimate was adjusted.

For determining the phone price discount, variables from the groups 'contract' and 'phone' are used. In both groups, there are other variables that were not used in the end. The data usage group contains frequencies of usage of data-based services. The last group contains standard demographic variables, from which only the age is used in an estimation later on.

2.3.2 Model estimation and performance

In this subsection, the model specifications will be estimated through several variants. Both, the model specification and the estimation variant influence the interpretation of the estimated unit prices, the prediction accuracy and the resulting hedonic price indexes. Therefore, a well-specified model is a central element of a hedonic price index. This subsection consists of an extensive analysis of the different model specifications and estimation variants. The indexes to compare the prices of Swisscom and Orange are presented afterwards, in subsection 2.3.3. The results of this subsection show that no model specification outperforms the others significantly. The estimations can be improved by grouping variables, as well as removing influential observations.

The aim is to achieve a better understanding of model performance under different estimation methods. For every estimation method, all four model specifications are estimated once for Swisscom and Orange data. This split according to providers allows for the observation of specification and estimation performance in different systems of tariff plans. The data contain the third and fourth quarters of 2012 and the first of 2013. Not enough Swisscom observations are given for earlier time periods, so the corresponding Orange observations are skipped.

This long subsection is divided into five parts. In the first four parts, model specifications are estimated through different methods. Starting with complete models in the first part, variables are then grouped in the second part. This mainly results in more consistent coefficient estimates, for example, fewer negative unit prices and more realistic unit price levels. Still, many outliers disturb the estimations in the grouped variant, so influential observations are also removed in the third part. The fourth part excludes influential observations for models with single variables, such as those in part one. Finally, in the fifth part, models and estimation methods are compared, and the interaction between them is summarised.

By doing Jarque-Bera tests to control for residual distribution, Breusch-Pagan tests for heteroscedasticity and RESET tests for model specification, estimations are evaluated from multiple perspectives. No specification and estimation method is able to pass all of the tests. This is done mainly to discover where there are problems within the different specifications and estimation methods. The small sample still poses problems; perhaps a larger sample would resolve many issues on its own. Despite testing for multiple statistical problems, in the end, most important for a hedonic price index is the predictive power of the model. This is measured by the adjusted R-squared. Further analyses regarding prediction accuracy should be carried out in future research, as argued more precisely in the outlook in subsection 2.4.2.

Basic specifications with single variables

The model is estimated by ordinary least squares (OLS). All four model specifications, namely linear (lin), semi-log (log), Box-Cox (BC) and decreasing marginal price (dmp), are each estimated on Swisscom (S) and Orange (O) data from July 2012 to March 2013. First model specifications, followed by underlying data, are indicated at the top of each column. The Swisscom subsample contains 215 observations and that of Orange 115. Each of the explanatory variables are included individually in the model specifications.

The estimation of the Box-Cox-coefficient on the full sample yields $\widehat{\lambda} = 0.3$, and is therefore used to transform the dependent variable accordingly. As discount factor for the decreasing marginal price specification, $\theta = 0.3$ is chosen. The rather low level is favoured over higher ones in order to make a significant difference compared to the linear specification. Only the discount for phones was not discounted, because the quantity is always just one phone, despite the fact that the variable is scaled in Swiss francs. The intention of the dmp specification is to discount the quantities of consumed units. The quantity of the phone discount is always 1 if a consumer received a discount or 0 if he did not.

Note that in estimations 'dmp S' and 'dmp O', the explanatory variables are transformed as suggested by the model, and in the end, the corresponding coefficients are finally not for the same variables as in the first six estimations. Even though a consumer could supply multiple bills, no special form of standard error estimation for the coefficients is used. The estimations of the standard errors of coefficients could have been corrected for clusters, as done in chapter 4. This is not done for three reasons. First and most importantly, the values of the predicted invoiced amounts are not affected by standard error correction. Only the values of the predicted amounts (which are not affected by a standard error correction) are used for the indexes, not the standard errors. Secondly, in further applications, especially for official statistics, observations should be independent. Finally, a broad set of tests that analyse more relevant issues for the resulting indexes have already been applied.

The interpretation of the eight estimations in table 2.6 starts with the coefficients. The coefficients of the linear model specification (lin) can be interpreted as the marginal price per unit consumed in Swiss francs (CHF). In the semi-log specification (log), the prices are semi-elasticities. If the consumption of unit j increases by 1, the invoiced amount increases in average by $100 \cdot \widehat{\beta}_j\%$. Variable-specific comments and interpretations of the estimated coefficients follow. A coefficient is considered significantly different from 0 if its p-value (from the t-statistic) is below 5%. I will comment more on the results in table 2.6 in the following paragraph. Again, the results are neither representative of Switzerland nor of any specific demographic subgroup. Additionally, the sample size is rather small. Nonetheless, all observations are real bills based on actual consumption and tariff plans from Swiss providers. Consequently,

Table 2.6: Specifications with single consumption variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Constant	36.510***	44.231***	3.452***	3.706***	7.716***	8.644***	18.209**	31.772**
	(2.937)	(5.171)	(0.062)	(0.092)	(0.250)	(0.428)	(6.185)	(10.878)
Minutes fix net	0.039	−0.030	0.001	−0.001	0.004	−0.003	0.591	1.989
	(0.030)	(0.046)	(0.001)	(0.001)	(0.003)	(0.004)	(1.397)	(2.455)
Minutes mobile on	−0.032**	0.021	−0.000	0.001	−0.002**	0.004	−0.981	−0.405
	(0.010)	(0.035)	(0.000)	(0.001)	(0.001)	(0.003)	(1.097)	(1.928)
Minutes mobile off	0.164*	0.456***	0.002	0.007***	0.012*	0.038***	5.203***	8.532***
	(0.064)	(0.065)	(0.001)	(0.001)	(0.005)	(0.005)	(1.429)	(2.141)
SMS	−0.002	−0.030	0.000	−0.000	0.001	−0.002	−0.332	−1.716
	(0.019)	(0.029)	(0.000)	(0.001)	(0.002)	(0.002)	(1.641)	(2.080)
MMS	0.470	0.756	0.004	0.004	0.027	0.033	5.934**	16.647***
	(0.308)	(1.106)	(0.006)	(0.020)	(0.026)	(0.092)	(1.924)	(4.655)
MB	0.019***	0.003	0.000***	0.000	0.001***	0.000	4.584***	1.023
	(0.002)	(0.007)	(0.000)	(0.000)	(0.000)	(0.001)	(0.613)	(1.393)
CH minutes roaming	0.078**	0.162	0.001	0.003	0.005*	0.016	4.871*	2.091
	(0.025)	(0.248)	(0.001)	(0.004)	(0.002)	(0.021)	(2.340)	(3.466)
CH SMS roaming	−0.411	0.791***	−0.003	0.012***	−0.026	0.065***	−5.931**	4.401
	(0.246)	(0.165)	(0.005)	(0.003)	(0.021)	(0.014)	(1.986)	(2.831)
Roaming minutes	1.624***	5.050***	0.027***	0.048***	0.137***	0.295***	13.496***	11.907**
	(0.366)	(0.669)	(0.008)	(0.012)	(0.031)	(0.055)	(2.951)	(4.418)
Roaming SMS	0.247	0.570	0.005	0.006	0.024*	0.035	5.849**	4.420
	(0.135)	(0.395)	(0.003)	(0.007)	(0.011)	(0.033)	(1.819)	(4.755)
Roaming MMS	13.769	−17.911	0.246	−0.407	1.197*	−1.843	2.832	18.133
	(7.000)	(22.228)	(0.147)	(0.394)	(0.596)	(1.841)	(9.902)	(24.363)
Roaming MB	1.003***	1.137***	0.001	0.014*	0.027	0.081**	16.408***	17.805***
	(0.214)	(0.320)	(0.004)	(0.006)	(0.018)	(0.027)	(4.491)	(4.379)
Phone discount	0.210	−0.420*	0.011**	−0.003	0.038*	−0.024	−0.345	−0.619*
	(0.188)	(0.206)	(0.004)	(0.004)	(0.016)	(0.017)	(0.200)	(0.237)
N	215	115	215	115	215	115	215	115
adj. R-squared	0.719	0.676	0.479	0.510	0.627	0.599	0.695	0.592
Reset	10.213***	9.979***	11.400***	1.742	13.554***	1.997	5.573**	13.754***
Jarque-Bera	356.379***	7.805*	6666.716***	120.464***	3118.213***	14.577***	446.388***	97.213***
Breusch-Pagan	58.184***	49.096**	6.260	8.3381	26.290*	13.442	46.161***	44.493***

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera tests with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

the results characterise and represent a considerable part of the reality of the Swiss market for mobile communication services. The major difference from a 'representative sample' is that contracts for young people or students are represented more than others.

Some estimated coefficients seem plausible and are significant in the linear specification. For example, an additional megabyte for a Swisscom customer costs in average 0.019 CHF. Other estimates are not plausible at first glance. For example, minutes called on the fix net by Orange customers cost in average −0.030 CHF. However, most negative estimates are not significantly different from 0, as indicated by the *t*-statistics. This could be interpreted as a flat-rate element in the tariff plan, where price and consumption are independent. Remember that the sample contains a lot of bills supplied by students. In contracts for students, communication in Switzerland is usually covered by a flat-rate element, so the (explicit) marginal unit price is equal to 0. Non-significant coefficients for communication in Switzerland can thus be explained by flat-rate elements of the tariff plans.

In the linear specifications (lin), there are significantly negative coefficients, such as, for example, for Swisscom 'Minutes mobile on'. This estimate is generally not plausible. Providers' tariff plans can be observed, and no provider pays money back for consumption through negative explicit marginal unit prices. There are two possible explanations for why the implicit marginal unit price of 'Minutes mobile on' could be negative. Firstly, when consumers can call on the net owned by the provider for free or even for a negative implicit marginal unit price, this provides an incentive for the consumer to motivate other potential consumers to sign a contract with this provider. Secondly, providers also earn money with calls which are made on their own net. The distinction between explicit and negative implicit marginal unit prices outlines a possible explanation for this particular estimation result. Alternatively, the statistical explanation is that the 'true' implicit marginal unit price is (in average) equal to 0, but the OLS-estimation causes a slight deviation.

If only prediction within a double-imputed price index is considered, estimated negative coefficients are a minor problem. But if, for example, the model is used with an index using the characteristics method, then prices for single predefined consumption vectors are predicted. In this case, negative coefficients may lead to undesired results. Some estimated coefficients, such as 'Roaming MMS', have absolutely unrealistic magnitudes. Swisscom clients pay, according to the estimation, 13.769 CHF for one additional MMS abroad, whereas Orange customers receive 17.911 CHF for one. These very specific extreme estimates emerge because 'Roaming MMS' are very rarely consumed units, so the estimation reacts sensitively.

An interesting variable is the monthly discount on phones, because it should maintain the independence between consumption and the contract. However, it does not behave consistently. A large part of the discount on the phone 'vanishes' in the constant, as shown precisely by estimating specifications without a constant, see appendix A.1.1. Additionally, if the constant is suppressed, the coefficients can be interpreted as average implicit unit prices, which is not possible as long a constant is in the specification.

With single consumption variables, the semi-logarithmic specification shows no coefficients that are significantly negative. All of the other three specifications contain significant negative coefficients. For interpreting the coefficients, among the different specifications, the semi-logarithmic model is clearly the best. Also, in the overall estimation performance with regard to all tests, the semi-logarithmic specification performs better than the others. Recall that the adjusted R-squared cannot be compared between the different specifications because of the dependent variables have been transformed differently. Reset, Jarque-Bera and studentised Breusch-Pagan tests are carried out to evaluate the estimations.

Six out of the eight estimations have significant RESET test statistics. This is an indication that the model specifications could be improved by adding higher-order terms of variables. Only the log and BC specification for Orange data passed, but in general the models could be specified better. The problem with adding higher order terms is that the interpretation of the coefficients as marginal unit prices is no longer possible. Therefore, instead of changing the specification, estimation methods are modified later on. The Jarque-Bera tests control for the normal distribution of the residuals, which is a major assumption of OLS. Residuals distributions are not normal over all estimations. Finally, the studentised Breusch-Pagan test statistic indicates that in the semi-logarithmic specification, no heteroscedasticity is present. In all other specifications, t-

statistics might be partially invalid, and significances of the coefficients should not be interpreted over-confidently. Nevertheless, the levels of coefficients can still be interpreted.

Overall, the models have relatively high explanatory power, which is important for predictions and the subsequent index construction. The semi-logarithmic specification seems to fit best with single variable estimation. In the other specifications, the main problem is the negative and non-significant estimates of coefficients, which are not desirable. Negative coefficients can cause predicted prices (invoiced amounts) to be negative. This is generally not plausible, and it can be problematic for the index construction, as it can make the growth factors of price levels negative.

Specifications with grouped variables

The aim of grouping variables is mainly to avoid negative and non-significant coefficients. Coefficients should not - by the nature of the observed tariff plans - be estimated significantly negative. Even though in the last part, which discussed single variable estimations, reasons for slightly negative implicit marginal unit prices for communication in Switzerland are provided, strong negative magnitudes are generally not plausible, and they are probably caused by statistical issues. Additionally, negative coefficients cause problems for the construction of the indexes. The variables are grouped for the next set of estimations, as described in table 2.4. This is especially helpful for units that are rarely consumed, such as all roaming units.

The dmp discount factor remains at $\theta = 0.3$. The estimated coefficient for the Box-Cox specification for grouped variables is $\widehat{\lambda} = 0.4$. Besides that, and the grouping of variables, everything is similar to the estimation of specifications with single consumption variables. The main change in interpretation when grouping consumption variables is that coefficients are no longer interpretable as price or semi-elasticity for a single unit, but rather for a group of similar units. The trade-off at first glance is the loss of some precision by reducing the number of explanatory variables in order to obtain more reasonable estimates for grouped variables. The results are summarised in table 2.7.

As can be seen, grouping variables has an effect on the significance and non-

Table 2.7: Specifications with grouped consumption variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Constant	35.735***	52.788***	3.458***	3.849***	6.202***	7.349***	10.539	29.220*
	(3.042)	(7.018)	(0.061)	(0.110)	(0.176)	(0.361)	(6.265)	(12.414)
Minutes	0.001	0.032	0.000	0.001*	0.000	0.002*	1.785	6.584**
	(0.009)	(0.021)	(0.000)	(0.000)	(0.001)	(0.001)	(1.098)	(2.010)
Text messages	0.012	−0.001	0.000	0.000	0.001	0.000	0.822	0.464
	(0.015)	(0.040)	(0.000)	(0.001)	(0.001)	(0.002)	(1.472)	(2.273)
MB	0.020***	0.010	0.000***	0.000	0.001***	0.000	4.925***	0.107
	(0.002)	(0.009)	(0.000)	(0.000)	(0.000)	(0.000)	(0.611)	(1.531)
Roaming minutes	0.136***	1.183***	0.002***	0.014***	0.007***	0.052***	10.800***	10.471***
	(0.022)	(0.210)	(0.000)	(0.003)	(0.001)	(0.011)	(1.938)	(2.599)
Roaming text	0.374**	−0.024	0.007*	−0.005	0.023**	−0.015	4.722**	2.011
	(0.142)	(0.521)	(0.003)	(0.008)	(0.008)	(0.027)	(1.789)	(4.823)
Roaming MB	1.361***	1.867***	0.006	0.024***	0.033*	0.087***	18.345***	27.067***
	(0.222)	(0.424)	(0.004)	(0.007)	(0.013)	(0.022)	(4.247)	(4.505)
Phone discount	0.190	−0.513	0.011**	−0.006	0.027*	−0.023	−0.277	−0.575*
	(0.201)	(0.271)	(0.004)	(0.004)	(0.012)	(0.014)	(0.206)	(0.247)
N	215	115	215	115	215	115	215	115
adj. R-squared	0.662	0.357	0.425	0.245	0.533	0.291	0.650	0.462
Reset	1.597	24.574***	8.171***	7.630***	4.775**	10.724***	3.350*	3.368*
Jarque-Bera	771.525***	90.284**	4240.838***	24.131***	275.305***	3.381	456.553***	117.020***
Breusch-Pagan	12.142	46.053***	5.708	10.580	8.474	23.319**	27.821***	28.529***

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera tests with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

negativity of coefficients, especially in the linear model. Some specific observations are listed below. In the linear model, all Swisscom coefficients are positive, and most are significant at the 5% level. Minutes, text messages and the discount are not significant. Minutes and text messages are mostly covered by flat rates, so it is reasonable that their coefficients are not significant. The linear specification shows some problems with the Orange tariff system. Only roaming units and the constant are significantly different from zero. This may be caused by flat rates, but it does not seem realistic when inspecting the underlying contracts. In the semi-logarithmic, BC and dmp specifications, coefficients' behaviour is similar to that found in the linear model. The coefficients for monthly discounts still do not show consistent influence over all estimations.

The key benefit of grouping consumption variables is that estimated coefficients overall become more significant and obtain reasonable magnitudes or levels. The explanatory power of the models decreases, especially for Orange tariff plans. Nevertheless, because only a few estimated coefficients are negative, negative predicted invoiced amounts can be avoided. Consequently, the index creation process is facilitated greatly by grouping variables, as shown more clearly in 2.3.3. Whether grouping only seems helpful due to the small sample size is an open question. Perhaps, with a larger sample size, grouping would no longer improve estimates that much.

Compared to single variable estimation, test performance did not change significantly. Besides the linear specification of Swisscom, all models still have specification problems, as indicated by the RESET test. Also, the residual distributions are problematic, as indicated by the Jarque-Bera tests. The BC-specification has one residual distribution that is normal, which is intended with the use of a BC-specification. As seen in the Breusch-Pagan tests, heteroscedasticity is less frequently present.

The main benefit of grouping variables is that the quality of the estimated coefficients is improved. They obtain reasonable magnitudes, positive signs and are more often significantly different from zero. All specifications perform approximately equally; only the dmp-specification does slightly worse.

Removing influential observations with grouped variable specifications

By grouping variables, the estimates are improved, but the specifications still show problems with model specification, residual distribution and heteroscedasticity. One way to deal with heteroscedasticity issues would obviously be to use a heteroscedasticity consistent estimation of standard errors. However, if that alone is done, problems with specification and residual distribution still remain. These problems are often caused by outliers. One possible way to prevent these problems is to remove influential observations in the underlying data.

As with grouping, removing influential observations changes the interpretation of the estimated prices and thus the indexes. If, for example, the 10% of the most influential observations (or outliers) are dropped, prices will be estimated for the broad majority of consumers. Nonetheless, extreme cases, which clearly also belong to the real world - such as very intense roaming - are excluded. Providers with high unit prices in these segments would benefit from a lower index value. On the other hand, data quality might be bad, such that, for example, a typo that changes 1 'Roaming MMS' to 1000 would be correctly excluded. As long as data quality is good, removing influential observations influences the analysis by cutting out elements of consumption.

Belsley et al. (1980) suggest DFFITS as a measure of influence. By removing every single observation individually once from the complete sample, the influence on predicted prices compared to the observed prices for all observations is estimated. The resulting metrically scaled influence statistic for every single observation is compared to a cut-off value that indicates whether the observation is influential, thereby allowing for the creation of a binary distinction with values 'influential' or 'not influential'. The cut-off value is dependent upon a multiplier for tuning the strictness of removal, which is set manually. For this analysis, the cut-off multiplier is set to 1.5, as suggested by Staudte and Sheather (1990). All observations that have an influence (based on the complete sample) are excluded, resulting in a reduced sample. This procedure is not repeated for the reduced sample. With this configuration, between 5% and 15% of the observations are considered influential, as shown in table 2.8.

Compared to the estimation of grouped variables in table 2.7, several state-

Table 2.8: Removing influential observations, grouped variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Constant	29.645***	50.830***	3.456***	3.884***	6.045***	7.308***	11.325**	27.130***
	(2.045)	(4.879)	(0.046)	(0.078)	(0.145)	(0.256)	(4.152)	(7.532)
Minutes	0.011	0.066***	0.000	0.001***	0.000	0.004***	1.949**	6.301***
	(0.007)	(0.019)	(0.000)	(0.000)	(0.000)	(0.001)	(0.697)	(1.266)
Text messages	0.014	−0.018	0.000	0.000	0.001	0.001	1.154	2.198
	(0.010)	(0.028)	(0.000)	(0.000)	(0.001)	(0.001)	(0.927)	(1.511)
MB	0.020***	0.002	0.000***	0.000	0.001***	0.000	3.811***	−1.086
	(0.002)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.410)	(0.964)
Roaming minutes	0.092*	1.230***	0.002***	0.019***	0.007***	0.056***	8.923***	6.450***
	(0.042)	(0.251)	(0.001)	(0.004)	(0.002)	(0.013)	(1.420)	(1.814)
Roaming text	0.433***	−0.831	0.008*	−0.011	0.027**	−0.050	2.400*	28.787
	(0.122)	(1.057)	(0.003)	(0.006)	(0.009)	(0.052)	(1.115)	(16.027)
Roaming MB	4.016**	6.936***	0.008	0.074***	0.035	0.356***	20.004***	25.687***
	(1.449)	(1.667)	(0.007)	(0.015)	(0.035)	(0.082)	(3.487)	(3.651)
Phone discount	0.444**	−0.505**	0.011***	−0.009**	0.034***	−0.029**	−0.069	−0.328*
	(0.139)	(0.190)	(0.003)	(0.003)	(0.010)	(0.010)	(0.137)	(0.159)
N	198	102	203	99	201	96	193	98
adj. R-squared	0.591	0.374	0.511	0.451	0.523	0.424	0.667	0.626
Reset	3.146*	0.046	5.676**	1.641	3.228*	0.357	3.022	0.663
Jarque-Bera	50.804**	5.476	7.962*	1.289	29.289***	3.007	25.468***	1.456
Breusch-Pagan	7.016	12.058	5.804	4.175	4.358	4.080	6.710	5.766

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera tests with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

ments about the coefficients estimated with removing influential observations in table 2.8 can be made. First, coefficients are estimated with similar magnitudes. In particular, the discounts in the linear specification become significant. One is negative, the other positive. Discounts become significant in general.

Removing influential values, therefore, does not change significances, levels or signs to a large extent. However, as is expected with the removal of influential observations, overall estimation performance improves. Despite the small influence on estimated coefficients, the tests show clear improvements for the entire estimations. The RESET test does indicate that only three models have specification issues, compared to seven before. As seen in the Jarque-Bera test, four estimations might have non-normally distributed residuals, compared to seven before. The main improvement gained by removing influential values is that heteroscedasticity is no longer a problem. The adjusted R-squared change depends on provider and specification. The estimated coefficients, especially the t-statistics, become reliable. However, these improvements are 'purchased' at quite a high cost: dropping 5% to 15% of the observations, all of which belong to the effective consumption, if the data are correct.

In the end, it is a question of individual preference as to whether influential observations should be dropped in order to avoid heteroscedasticity. If no heteroscedasticity were present and data quality were good, then no significant benefits from removing influential observations would be obtained. As an alternate solution, a heteroscedasticity-consistent estimation of standard errors does not change anything in terms of the prediction of prices. This will make the t-statistics of coefficients reliable, if the residual distributions are normal.

Removing influential observations with single variable specifications

In the last variation of estimation, single variables are used, as in the first set of estimations in table 2.6, and influential values are removed as before. Again, DFFITS with a cut-off multiplier 1.5 is used, and around 5% to 10% of observations, depending on specification and data, are excluded. The results are summarised in table 2.9.

Table 2.9: Removing influential observations, single variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Constant	31.377***	38.640***	3.436***	3.627***	6.081***	6.643***	16.994***	27.460***
	(1.997)	(4.049)	(0.045)	(0.071)	(0.138)	(0.231)	(4.308)	(6.468)
Minutes fix net	0.049*	−0.032	0.002***	−0.000	0.003	−0.001	1.913*	0.091
	(0.025)	(0.049)	(0.000)	(0.001)	(0.002)	(0.002)	(0.919)	(1.543)
Minutes mobile on	−0.020**	0.051	−0.000*	0.002**	−0.001*	0.004*	−1.139	1.716
	(0.007)	(0.028)	(0.000)	(0.001)	(0.001)	(0.002)	(0.704)	(1.254)
Minutes mobile off	0.195**	0.413***	0.002	0.007***	0.012**	0.023***	4.565***	7.866***
	(0.064)	(0.066)	(0.001)	(0.001)	(0.004)	(0.004)	(0.895)	(1.308)
SMS	0.004	−0.011	0.000	−0.000	0.001	−0.000	−0.933	0.622
	(0.012)	(0.023)	(0.000)	(0.000)	(0.001)	(0.001)	(1.077)	(1.339)
MMS	0.155	4.510	0.001	0.103	0.007	0.107	3.520**	10.642**
	(0.205)	(2.543)	(0.005)	(0.061)	(0.015)	(0.138)	(1.208)	(3.391)
MB	0.018***	0.000	0.000***	0.000	0.001***	0.000	4.633***	−0.791
	(0.002)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)	(0.414)	(0.875)
CH minutes roaming	0.070	0.351	0.001	0.006	0.004	0.039	6.698***	2.743
	(0.041)	(0.408)	(0.001)	(0.007)	(0.003)	(0.023)	(1.646)	(2.416)
CH SMS roaming	−0.428	0.932**	−0.003	0.017***	−0.014	0.059***	−5.298***	5.970**
	(0.236)	(0.320)	(0.004)	(0.005)	(0.013)	(0.017)	(1.275)	(1.790)
Roaming minutes	1.295	2.059	0.033**	0.032	0.069	0.056	7.030**	3.995
	(1.067)	(1.472)	(0.012)	(0.022)	(0.075)	(0.067)	(2.313)	(2.999)
Roaming SMS	0.455***	−0.567	0.008*	−0.013	0.027**	0.003	4.219***	2.042
	(0.117)	(0.904)	(0.003)	(0.016)	(0.010)	(0.019)	(1.140)	(4.004)
Roaming MMS	0.995	−37.678	0.344*	−0.685	0.132	−2.858	7.312	22.812
	(12.210)	(33.319)	(0.159)	(0.395)	(0.836)	(1.751)	(6.107)	(14.558)
Roaming MB	1.066	3.542	−0.011	0.019	−0.012	0.163	12.927***	18.519***
	(0.601)	(2.175)	(0.012)	(0.013)	(0.042)	(0.119)	(3.713)	(3.386)
Phone discount	0.428**	−0.127	0.009**	−0.002	0.029**	−0.009	−0.006	−0.117
	(0.130)	(0.164)	(0.003)	(0.003)	(0.009)	(0.009)	(0.132)	(0.159)
N	191	100	197	98	188	99	197	100
adj. R-squared	0.729	0.634	0.592	0.600	0.616	0.625	0.767	0.737
Reset	2.349	1.235	5.854**	4.313*	4.761**	3.988*	11.810***	2.765
Jarque-Bera	24.497***	9.443**	11.343**	1.250	6.349*	6.065*	22.229***	1.484
Breusch-Pagan	10.937	13.213	16.727	12.686	13.104	12.346	25.058	13.068

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera tests with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

As in the single variable estimation, the estimated coefficients remain very problematic. For example 'Roaming MMS' is estimated as -37.678 for Orange. These unrealistic estimates can be very problematic for predictions because negative growth factors might result. The adjusted R-squared are comparable to those in estimations in which influential observations were not removed with single variables.

As already seen in the estimation for grouped variables, removing influential values removes the presence of heteroscedasticity. Additionally, the Jarque-Bera tests are still significant six times. The model specification remains an unsolved problem, as five RESET tests are significant.

As long as the estimated coefficients do not yield consistently reasonable levels and signs, there is no use of removing influential observations to avoid heteroscedasticity and to make t-statistics reliable. Perhaps with a large sample that covers a greater number of rare consumption units, such as all roaming categories, the combination of single variables and the removal influential observations might be reasonable. Whether removing influential observations and single consumption variables can be a valid combination is an open question for further research.

Index construction: linear specification with grouped variables

Section 2.3.2 is closed by summarising the most important results for specifications and estimation methods. First, estimation methods are compared, and then the model specifications are evaluated. Finally, a linear specification with grouped variables, without removing influential observations, is chosen to create the indexes.

Besides the standard OLS estimation with single variables, two modifications are applied: grouping variables and removing influential observations. Grouping variables results in nearly fully reasonable estimations of coefficients and avoids large negative roaming coefficients. The cost of grouping is that unit prices cannot be interpreted anymore for units as they are billed. But overall, especially for the construction of indexes, the benefits of grouping clearly dominate. As mentioned before, with a significantly larger sample size, grouping might no longer be necessary.

Removing influential variables is the second distinction in estimation methods. By removing influential observations, most heteroscedasticity issues can be avoided, and *t*-statistics of estimates are reliable (if residuals are normally distributed). Whether influential observations are removed or not is also a question of data quality. If data quality is not very good, removing influential observations could help to sort out bad observations (for example, typing errors). But as long as data quality is not expected to be bad, dropping influential variables cuts out a part of reality and may favour providers with specific tariff systems over others. Presence of heteroscedasticity versus including complete consumption is the trade-off, and as long as only indexes are the object of interest, all observations should be considered.

For the index construction process, treating all providers with corresponding tariff systems equally is preferred. Therefore, for the index calculations afterwards, specifications with grouped variables are used, and influential observations are not removed. A specification must be chosen as the second step.

Four model specifications were analysed. Whereas the linear specification benefits from very simple interpretation of the coefficients, in the semi-log and Box-Cox specifications, the dependent variables are transformed. Theoretically, the benefit of these transformations is to have normally distributed residuals, but this is not observed. The dmp specification discounts consumption, seems reliable when influential observations are removed and may be a reasonable way to model mobile communication prices. However, because hedonic price indexes are new in mobile communication, a simpler, more straightforward specification should be chosen.

In the grouped variable estimations, no model specification is clearly the best with regard to estimated coefficients and test statistics. For the index estimation in section 2.3.3, the linear model will be used. It is the simplest specification and the best to interpret with marginal unit prices, which are quite interesting in the mobile communication context. With the use of grouped variables in a linear specification, it is not the technically best model used, but it is the easiest to understand. When interpreting indexes, this should not be neglected because data, model specification, estimation method and index formula all influence the interpretation.

For hedonic price indexes, the predictive power of a model is important. In this analysis, the predictive power was measured by the adjusted R-squared. Another way to control for prediction quality would be cross-validation, as an out-of-sample measure. To compare prediction quality across specifications with differently transformed dependent variables, the transformed dependent variables would have to be re-transformed.

2.3.3 Constructing hedonic price indexes

In this section, double-imputed Fisher and (modified) Törnqvist indexes are constructed to compare Swisscom and Orange prices over the quarters Q3.12, Q4.12 and Q1.13. Linear models with grouped variables are used. First, unit prices are estimated per provider and quarter. Then, the problems of negative predicted prices are discussed and resolved by removing negative predictions. In the third part, indexes are constructed and evaluated.

Model estimation over providers and time

As mentioned before, a linear specification with grouped variables is used as the basis for the estimation of unit prices. Unit prices are estimated for three quarters, Q3.12, Q4.12 and Q1.13, and three providers: Swisscom (S), Orange (O) and the entire sample (M). The results are presented in table 2.10.

With the exception of Orange in Q1.13, the regressions have more than 30 degrees of freedom. However, there are not enough observations to create stable results. Nonetheless, here, the aim is to illustrate how to construct indexes. For this purpose, the sample size suffices. The explanatory power of most estimations is acceptable, even though the number of observations is quite small. More specific comments on coefficients are listed below.

'Minutes' are estimated on reasonable magnitudes with mostly positive signs, but these are not significant. 'Roaming minutes' prices are partially estimated to be relatively high. The same goes for 'Roaming text' for Orange in Q1.13. The only two variables whose coefficients are estimated significantly negative are 'Roaming text' and 'Phone discount'. As in subsection 2.3.2, 'Roaming text' is the most difficult unit group, probably due to the relatively low num-

Table 2.10: Model estimation for index construction

	Q3.12 M	Q3.12 S	Q3.12 O	Q4.12 M	Q4.12 S	Q4.12 O	Q1.13 M	Q1.13 S	Q1.13 O
Constant	43.609***	37.340***	48.899***	41.393***	32.969***	67.691***	26.550***	28.590***	21.351
	(4.966)	(6.692)	(7.776)	(4.054)	(3.742)	(9.880)	(5.877)	(4.994)	(10.296)
Minutes	0.014	0.008	0.052*	0.012	0.010	0.038	0.005	−0.001	0.086
	(0.016)	(0.021)	(0.024)	(0.012)	(0.012)	(0.028)	(0.015)	(0.012)	(0.040)
Text messages	0.024	0.067	0.002	0.016	0.019	−0.088	0.019	0.005	0.039
	(0.037)	(0.052)	(0.048)	(0.021)	(0.018)	(0.059)	(0.022)	(0.016)	(0.066)
MB	0.015***	0.017***	0.005	0.018***	0.019***	0.007	0.006	0.011***	−0.001
	(0.004)	(0.005)	(0.014)	(0.003)	(0.002)	(0.011)	(0.004)	(0.003)	(0.013)
Roaming minutes	1.564***	2.004***	0.752	0.135***	0.120***	2.743***	0.009	0.102**	0.221
	(0.322)	(0.416)	(0.513)	(0.029)	(0.025)	(0.546)	(0.042)	(0.037)	(0.243)
Roaming text	−0.092	0.040	−0.412	0.396	0.695*	−1.235	0.783*	0.570*	4.152
	(0.196)	(0.213)	(0.549)	(0.327)	(0.280)	(1.297)	(0.304)	(0.218)	(6.998)
Roaming MB	2.013***	1.148	6.554***	1.084***	1.093***	1.476*	6.235***	2.623**	5.672
	(0.540)	(0.577)	(1.270)	(0.220)	(0.228)	(0.598)	(0.961)	(0.952)	(9.372)
Phone discount	−0.168	−0.248	−0.375	−0.103	0.186	−1.122**	1.132***	1.010**	0.946
	(0.247)	(0.370)	(0.315)	(0.205)	(0.265)	(0.340)	(0.302)	(0.327)	(0.509)
N	109	66	43	151	99	49	75	50	23
adj. R-squared	0.604	0.708	0.486	0.563	0.749	0.473	0.637	0.720	0.881

Note: The dependent variable in all estimations is the monthly invoiced amount. All estimations are for a quarter (Q) and a provider: entire market (M), Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N) and the adjusted R-squared are reported in the second part of the table.

ber of 'Roaming text' units consumed. How to explain and prevent negative estimates for the phone discount is described in detail in appendix A.1.1. However, estimated negative marginal unit prices might cause negative predicted invoiced amounts.

Removing negative predicted prices

By using the double-imputation method, only predicted, and no observed, prices (invoiced amounts) are used to construct indexes. In the Fisher index (2.7) with implicit expenditure weights, predicted prices are aggregated. Negative estimates of invoiced amounts are neither desired nor realistic, but they still allow the computation of the index. Negative predictions 'vanish' in the aggregate. It is impossible to calculate a Fisher index when a sum in the Laspeyres or Paasche indexes, and therefore the entire index, becomes negative. This is not the case here.

In the modified Törnqvist (2.10) index, just one negative price prediction makes calculating an index impossible. Remember that, instead of Laspeyres and Paasche indexes, this index uses their geometric pendants, as in formulas (2.11) and (2.12). In both, for each observation, a growth factor is first determined and then averaged by the geometric mean. A negative growth factor for an invoiced amount is not realistic. Additionally, and even more importantly, by using the geometric mean, $1/n$ is in the potency, which is smaller than 1. The mean would not be a real number anymore, which would make index calculation impossible.

For the following index calculations, the (only) one negative predicted price is excluded for Törnqvist, as well as for Fisher. Theoretically, it could have been left in the data for Fisher. But it is more convenient to compare differently calculated indexes when they are based on identical data. Removal is not a very elegant approach, but it is necessary to calculate the Törnqvist index. In this context, it is very important to have well-specified models with non-negative estimated coefficients.

Chained Fisher and Törnqvist price indexes

Based on the reduced data, Fisher and Törnqvist indexes are formed for every quarter. The market index (M) with all observations of each quarter is equal to 100 points. Then, indexes for Swisscom (S) and Orange (O) are constructed for each quarter, as shown in table 2.11. Fisher indexes are on the left half of the table, and Törnqvist indexes are on the right. All indexes are constructed as described in the theoretical section.

For the interpretation of the results, it is necessary to keep the model specification and the estimation method in mind. The effect of grouping variables should have minor effects on the interpretations. Also, using a linear model specification does not complicate the interpretation of the index, which is a reason to choose both. A 'dmp' model specification, for example, would complicate the interpretation significantly. Remember that double-imputation is applied, so all prices used are predicted and not observed. With single imputation, the prices that can be observed would be used, and the hypothetical ones be predicted. However, comparing equally constructed values is preferred.

The Fisher index describes a provider's price level relative to the market index (all observations within a quarter). Prices or the total costs of the aggregated consumption are compared. Observations with high consumption obtain automatically higher weights. In contrast, the Törnqvist index measures the relative price for the average consumer. All consumers receive an identical weight through the use of the geometric means of growths factors. In this way, single observations cannot have such a high influence on the indexes as those with high consumption in the Fisher index.

Keep in mind that the sample is not entirely representative for Switzerland; the index values in table 2.11 are only valid for the underlying sample.[4] The

[4]Additionally, the indexes are based on random variables, such as consumed units and billed amounts, so an indicator of the statistical reliability or significance of the indexes should be provided. This could be done with confidence intervals. But applying confidence intervals to (double-imputed superlative) hedonic price indexes is not state of the art, even though it is statistically desirable. Confidence intervals could be estimated by a non-parametric approach, as in Beer (2007), who estimated confidence intervals for elementary indexes. The general approach would be to use bootstrapping (or a similar method) to estimate the hedonic function for every bootstrapped sample. Then, based on the complete data set, an index value is predicted for each estimated hedonic function. This results in a distribution of

Table 2.11: Indexes with base period t

	Fisher			Törnqvist		
	M	S	O	M	S	O
Q3.12	100.00	95.35	105.14	100.00	93.93	102.98
Q4.12	100.00	92.69	137.17	100.00	91.38	115.25
Q1.13	100.00	98.25	121.62	100.00	100.20	111.50

Note: Swisscom (S) and Orange (O) prices are compared to the entire sample or market (M). All price comparisons are made within one of the quarterly periods, Q3.12, Q4.12 and Q1.13. The Fisher index is reported on the left and the Törnqvist index on the right.

interpretation of the index values can now begin. First and most importantly, overall Swisscom prices are lower than those of Orange. This result contradicts the official statistics of the Federal Office of Communications, in which Orange is clearly less expensive for small and medium consumption profiles, and in which, for intense consumption, an approximately equal price for both providers is reported. In Q3.12, Swisscom prices with 95.35 index points are about ten percent lower than Orange prices. In Q4.12 and Q1.13, there are quite large differences between Orange and Swisscom. Keep in mind that in Q1.13, only a few Orange observations are available. Note that in the Törnqvist index in Q1.13, both Swisscom and Orange obtain a higher price level than the market index (M). This is caused by the OLS estimation and an additional indicator that the number of observations is too small.

However, it is far more interesting to compare the differences between Fisher and Törnqvist indexes. The Törnqvist index estimates price levels more smoothly. The estimated index values are closer to each other in the Törnqvist index. This shows that single observations with intense consumption influence Fisher more strongly than they do Törnqvist. Especially in Q4.12, the difference between Orange and Swisscom in the Fisher index is twice as large as with Törnqvist. The trends in both indexes are the same, but the levels are different.

price indexes. Thus, for example, for a 95% confidence interval, the 2.5% and the 97.5% quantiles are non-parametrically determined. Because the focus of this first application of hedonic price indexes for mobile communication services is on elementary issues, such as the model specification and the index formulas, confidence intervals are not reported here. How to optimally estimate confidence intervals for these indexes is an open area for further research. Note that determining confidence intervals parametrically or theoretically is a complex issue because the indexes are sums, products and means of random variables with unknown (joint) distributions.

This result requires further analyses with a larger sample.

In the representation above, each quarter's full sample *M* is chosen as the base period. As described in section 2.2.3, chaining is applied to have only one single base period. Chaining is chosen over constructing indexes directly between different providers and periods. In this way, only period-specific consumption is included in the calculation process of indexes. In table 2.12, the full sample of Q3.12 is the unique base period.

Table 2.12: Indexes with base period 0

	Fisher			Törnqvist		
	M	S	O	M	S	O
Q3.12	100.00	95.35	105.14	100.00	93.93	102.98
Q4.12	83.23	77.14	114.16	92.70	84.71	106.84
Q1.13	82.53	81.10	100.38	91.93	92.04	102.50

Note: Swisscom (S) and Orange (O) prices are compared to the entire sample or market (M). All price comparisons are relative to the entire market (M) in Q3.12, thus, the price development over time is observable. The Fisher index is reported on the left and the Törnqvist index on the right.

Note that the differences in levels (index points) are not the same in the chained version in table 2.12 as in the unchained one. This is because all of the indexes in table 2.11 are chained or multiplied by an index value that is not equal to one. This changes the 'scales' of later periods.

Considering all model specifications, estimation variants, index formulas, index methods and representation forms, a very large number of different price indexes could have been constructed. The applied configuration seemed to be the best for this application of hedonic price indexes for mobile communication services. Note that in 'reality', years would likely be better time periods, but the underlying data favoured working with quarters.

Which index formula, Fisher, modified Törnqvist or some other, is applied in the end is, like every single choice in this analysis, a trade-off. The greatest weakness revealed in this empirical section is that price index values vary widely. Whether this is caused by sensitive model specifications or the small number of observations is an open question for further research. Because the sample is not representative, among other reasons, the indexes cannot be compared to the OECD method. Nonetheless, an attempt to compare both methods and their results is made in appendix A.1.2.

2.3.4 The influence of the consumers' age

The hedonic function and its specifications allow a broad set of detailed analyses related to communication prices. The model, which is set up to predict prices, can explain the basic composition of invoiced amounts dependent on consumed units. Because the invoiced amount is not dependent only on consumption, other variables can also help to explain it. Consider, for example, all special specifications of contracts and customer consultation. These influence the invoiced amount as well.

Contracts contain different specifications for different demographic subgroups. The most price-relevant specifications are made for young consumers and students. By simply adding the age of the consumer into the specification, the prices are also evaluated according to the age of the consumer. The estimated coefficients for age are significantly different from zero, thus the age of the consumer is - as expected - relevant to the invoiced amount and, consequently, the indexes. The open question is how to quantify this difference in Swiss francs.

Again, specifications with grouped variables are used, mainly because the interest lies in coefficients. Influential observations are removed to reduce heteroscedasticity and thereby obtain normally distributed residuals. The added variable 'Age' denotes the age in years of the contract holder. The models are again estimated for both providers and observations from Q3.12, Q4.12 and Q1.13. The results are summarised in table 2.13. This regression is similar to the so-called time-dummy method for the creation of hedonic price indexes. With the time-dummy method, instead of using index formulas and predicted prices, the specifications are complemented with a dummy for a time period or provider. The estimated coefficients for these dummies are then used to create the index.

'Age' is significantly positive in all estimations. The residual distributions for Swisscom estimations are not normal. Only the Box-Cox specification shows normally distributed residuals for Swisscom. The adjusted R-squared do not

Table 2.13: Impact of age on the invoiced amount

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Constant	−13.574**	22.058	2.681***	3.401***	3.512***	5.791***	−40.338***	−2.390
	(5.126)	(14.479)	(0.112)	(0.233)	(0.326)	(0.745)	(5.793)	(15.603)
Minutes	0.011	0.040*	0.000	0.001**	0.000	0.004***	1.774**	6.017***
	(0.006)	(0.017)	(0.000)	(0.000)	(0.000)	(0.001)	(0.593)	(1.352)
Text messages	0.016	0.032	0.000*	0.001	0.001*	0.003	1.226	3.018
	(0.008)	(0.034)	(0.000)	(0.001)	(0.001)	(0.002)	(0.806)	(1.786)
MB	0.021***	0.005	0.000***	0.000	0.001***	0.000	5.376***	0.057
	(0.002)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.358)	(1.056)
Roaming minutes	0.091**	1.206***	0.002***	0.018***	0.007***	0.063***	7.887***	7.070***
	(0.035)	(0.253)	(0.000)	(0.004)	(0.001)	(0.013)	(1.212)	(1.851)
Roaming text	0.445***	−0.599	0.008**	−0.009	0.026**	−0.035	3.772***	1.713
	(0.103)	(1.048)	(0.003)	(0.006)	(0.009)	(0.020)	(0.953)	(6.170)
Roaming MB	3.621**	4.516	0.000	0.058**	0.009	0.225***	16.922***	23.101***
	(1.217)	(2.387)	(0.006)	(0.018)	(0.030)	(0.057)	(3.056)	(3.696)
Phone discount	0.269*	−0.582**	0.009**	−0.010**	0.026**	−0.029**	−0.033	−0.448**
	(0.122)	(0.191)	(0.003)	(0.003)	(0.008)	(0.010)	(0.117)	(0.170)
Age	1.873***	1.062*	0.033***	0.016*	0.107***	0.052*	1.827***	0.890*
	(0.214)	(0.475)	(0.004)	(0.008)	(0.013)	(0.025)	(0.184)	(0.401)
N	193	101	200	99	195	98	195	97
adj. R-squared	0.720	0.313	0.642	0.411	0.664	0.455	0.788	0.579
Jarque-Bera	31.081***	4.328	22.500***	0.995	2.577	2.878	17.057***	1.968
Breusch-Pagan	11.895	13.883	8.171	14.137	13.361	9.742	15.449	4.967

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, Jarque-Bera tests with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

change significantly by adding 'Age'.

These results show that consumers tend to pay 1 to 2 CHF more per additional year of age. There are various reasons for this. First and most importantly, providers in Switzerland offer special discounts to young people and students. The age cap is usually 26 or 27 years. Part of the gap between young and old can therefore be deducted from different contracts. Additionally, young people usually have a lower income, and invoiced amounts for mobile communication can be a serious portion of their expenditures. Substitution of cheaper units may explain the result, like substituting SMS with Whatsapp messages. The estimated coefficient seems to be quite large. However, consider that most observations are from students or employees of the university. The age of the consumers is between 19 and 50 years, with most between 19 and 26. In a representative sample, the estimated coefficient is likely to be smaller.

The fact that young consumers have lower invoiced amounts could partially explain the relatively high prices of Orange in the indexes of the previous subsection. The average age of customers in the sample, weighted by the number of bills supplied, is 24.33 for Swisscom and 28.20 for Orange. Consequently, fewer Orange consumers benefit from special student discounts. This could cause some of the differences between the two providers' prices. Whether the indexes should be adjusted for the age is an issue for further research. One possible solution is to draw up a sample with similar distributions for the consumers' age for all providers. Alternatively, the influence of age on the invoiced amounts could be estimated, as shown. Then, a correction factor for asymmetric age distributions among providers could be applied on the indexes. As a third possibility, indexes could be estimated for demographic subgroups, such as 'student', 'adult' and 'business', instead of different consumption intensities, as is done with the profile method.

Applying hedonic price indexes on mobile communication services yields possibilities for additional analyses of tariff plans. Governments, for example, might be interested in issues that disadvantage consumers, such as rollover contracts.[5] Comparing and predicting prices for very precisely specified individuals or groups could be an interesting option for price comparison websites.

[5]Rollover contracts are contracts that are automatically extended after the minimal duration - unless they are explicitly terminated. My attempts to estimate the impact of rollover contracts on invoiced amounts yielded inconsistent results.

And, as a last example, contract-specific variables could be added to the estimations (such as the type or name) for providers to analyse their own tariff system.

2.4 Summary

This summary is divided into three parts. Firstly, the key findings are summarised in subsection 2.4.1. After discussing the results, an outlook is given in 2.4.2. Finally, in subsection 2.4.3, important practical aspects are mentioned.

2.4.1 Results

In this analysis, hedonic price indexes are applied to mobile communication services to adjust explicit service prices (invoiced amounts) to actually consumed units. The results from the empirical section show that overall, Orange is more expensive than Swisscom, which contradicts the official statistics. Even though the sample is not representative, it is shown that the profile method with minimal-cost contracts is not capable of accurate estimation and comparison of mobile communication prices.

Disadvantages of the profile method

In the OECD method, several important price-relevant variables, such as roaming, discounts on phones, demographic discounts and any other special nuances in contracts, are not implemented. Using hedonic price indexes allows us to capture all of these variables completely. Moreover, customer consultation is included by putting inefficient contracts at a disadvantage. The official method is simple to apply, but is a far less accurate estimator for mobile communication prices.

The hedonic function

The basic idea behind the model and the hedonic function is that, through a contract, consumed units are transformed into the invoiced amount. With this approach, all contracts can be treated equally. The only aspect of consumption that could not have been included was geographic network coverage, as well as partially the speed of data connections.

Besides these elements, all invoiced amounts are evaluated according to the effectively observed consumption. No assumption of perfectly rational and informed consumers is made. If a consumer is on a bad contract, it is included as this in the price index. Therefore, it does not suffice if a provider has a great contracts, but the consumers are not using them.

Model specification and estimation method

The hedonic function is specified in four variants: linear, semi-logarithmic, Box-Cox and decreasing marginal price. These specifications are estimated without modification, with grouped variables and without influential observations.

The linear specification allows for the direct interpretation of coefficients as unit prices, which helps validate the results. Based on known contracts, corresponding prices per unit and fixed cost, expectations about estimated unit prices can be formed for validation. The semi-log and Box-Cox specifications are mainly used to adjust for typical issues in price distributions.

Without any modification, especially rarely consumed variables obtain unrealistic and non-significant estimated coefficients. By grouping variables, the estimated coefficients can be improved greatly because they obtain reasonable magnitudes. Especially rarely observed roaming units disturb single variable estimations. Grouping variables solves this problem. Removing influential observations removes heteroscedasticity and makes standard errors reliable. Consequently, the coefficients and the corresponding significances can be interpreted. The explanatory power of all specifications and estimation methods is sufficient, but it can and should be improved. The Swisscom tariff plans are generally better explained than the tariff plans of Orange. The major reason for this is the number of observations, which is twice as large for Swisscom than for Orange.

No specification outperforms any other. Thus, for the index construction, the linear specification with grouped variables is used. The well estimated coefficients particularly support index construction. Influential values are not removed for index construction because all consumption should be included in the price index. Additionally, the focus is on optimal predictions, not on estimated coefficients.

Index formulas and values

Double-imputed Fisher and Törnqvist price indexes are used. The motivation for using double imputation is to compare equal to equal, that is, predicted prices with predicted prices and not observed ones.

Two index formulas are introduced. The first is a Fisher index, which describes the relative price of the aggregated consumption. This formula contains implicit weighting, which means that observations with intense consumption obtain relatively more weight. The second formula, a modified Törnqvist index, describes price development for an average consumer, meaning that every consumer or bill obtains the same weight.

Because the underlying database is not representative and contains a majority of bills from students, the results are only valid for this sample. Swisscom shows lower price levels than Orange over all estimated indexes. This is contradicts the official statistics, in which Orange is - especially for small consumption profiles - clearly cheaper than Swisscom. The extent to which this result is dependent on the methods or differences in the sample base is unknown. The results need to be verified by a representative sample.

In conclusion, hedonic price index methods can be adapted to mobile communication. This project was very general, and specific problems still need to be solved; more details are offered in the outlook in subsection 2.4.2. Also, practical issues need improvements as described in subsection 2.4.3.

2.4.2 Outlook

As this is a first application of hedonic price indexes on mobile communication services, some problems remain unsolved. Current limitations are discussed and further research is suggested in this outlook.

Implementation of service quality

The general model approach is to apply hedonic price indexes not for quality, but for quantity adjustment. On a theoretical level, the quality of connections remains an unsolved problem. The geographical coverage of networks is especially difficult to include.

If good information about the connectivity and speed with different contracts is given, this could be added to the linear model. An interaction term between 'MB' and 'Speed', for example, could suffice. How this or these interaction terms would be specified is open. Controlling for geographical network coverage seems much more complicated. What is understood by coverage, how it is measured and why it is important to consumers should be precisely defined. Additional, related questions include: Does an abandoned valley need connectivity? If so, how should it be weighted compared to a city centre? How should the quality of the connection influence such a measure? How should network quality be related to single observations, regarding their region-specific consumption?

Non-linear and non-parametric model specifications

Only linear specifications have been used so far. Consider the full range of existing contracts in the tariff systems. There are prepaid contracts without any fixed cost or flat rates with high fixed and no marginal cost. The relation of the invoiced amount to consumption within a provider's tariff system is unlikely to be linear. Non-linear functional forms could be viable. This modification would also require alternate estimation methods, so it is an area open for study. Also, non-parametric methods to predict prices could improve predictive power. The fact that non-parametric methods usually require less specifications could be especially useful.

Prediction performance analysis

The model specifications and estimation methods were evaluated according to the predicted coefficients, its significances and validities, residual distribution and heteroscedasticity. The explanatory power of specifications and estimation methods was monitored by the adjusted R-squared. However, the predictive power is key for hedonic price indexes using the double-imputation method. The indexes are based entirely on predicted prices, so these should be as accurate as possible.

The adjusted R-squared is an in-sample measure. Out-of-sample measures, such as cross-validation, could provide additional insight about prediction performance. Additionally, confidence intervals could and should be estimated. These are not applied in this study because the focus is on more basic issues, such as the hedonic function, its specification and the index formula.

Negative predicted prices

So far, the few prices that have been predicted to be negative have been removed. In the Fisher index, they are not a big problem. They vanish in the aggregate. In the modified Törnqvist index, negative growth factors might occur, and this does not allow the computation of an index. Negative predictions can be avoided by well-specified models and resulting positive predictions. Grouping variables solves a large part of this problem, because rare roaming observations are less relevant.

I did not find a more elegant method to handle this issue other than deletion. Perhaps further research will reveal a better solution.

Comparison to profile-based indexes

The double-imputed indexes can be compared to the minimal-cost approach of the Federal Office of Communications (2013). Through the characteristics method, an attempt to do so is made in appendix A.1.2. The main problem is that estimated unit prices of the hedonic indexes are based on the entire spectrum of units, whereas the official consumption profiles only contain minutes and text messages.

Even when the profiles are complemented by megabytes, roaming and discounts on phones are still excluded. Before comparing hedonic indexes based on complete consumption vectors to limited consumption profiles, as suggested by the OECD (2010), some problems need to be discussed. How should subsamples be formed for profile-specific price estimates? Are the given profiles realistic, or should they be completed by roaming units and phone discounts? Do the presented model specifications and estimation methods perform systematically poorly with the characteristics method, or is this caused by the reduced profiles or the small sample size?

Demographic and consumption-specific indexes

If a large and representative data sample is available, it could be interesting to compare not only prices across providers and over time, but also across different groups. Demographic splits could be made according to age groups or other categories, such as 'student', 'working' or 'retired'. Consumption splits, similar to the profiles in official statistics, can be done in a wide variety. Also, more specific consumption aspects, such as roaming or phone discounts, can be analysed with this approach. Recall that the age of the consumers has an impact on the indexes. Consequently, the distribution of the consumers' age across observations from all providers should be similar.

Data traffic and unit substitution

In the past decade, the introduction of data traffic in mobile communication has greatly altered consumption behaviour. Minutes and SMS can be substituted with data traffic (MB) with applications like Whatsapp or Skype. If data in a contract are cheap, or wireless LAN is available, costly units can be substituted with free data or at least data with a flat rate.

Motivated by this change, the consumer survey contains questions about usage frequencies for different types of applications. Because this sample contains a short time dimension, substitution behaviour could not be observed over several years. No surprising or unexpected results are obtained. Nevertheless, in a sample with a wider time interval, any effects of substitution on invoiced amounts could be verified.

2.4.3 Manual

This project is a first encounter with hedonic price indexes for mobile communication. As in every empirical project, there are some practical problems. In this last part of the conclusion, the most important 'practical' experiences that somehow did not belong to any previous section are shared.

Firstly, questions surrounding the sample and sampling process will be discussed extensively. Then, we take a closer look at the phone price discount and the consumer survey. Finally, billed services of other companies, the implementation of new units, the scaling of units and incomplete information are discussed.

Sampling frequency, size and source

In this project, quarters were chosen as periods, mainly because it is very difficult to obtain phone bills from more than a year ago. It is even more difficult to obtain all the information needed for the calculation of the phone discount as price paid and market prices of older phone types. In official statistics years are used as periods, which is reasonable. Providers usually change their tariff plans in yearly intervals. If the goal is 'continuous' price monitoring, data should be sampled at least once a year.

The sample size is another very important aspect. If sampled directly from consumers, a larger sample is more costly. Sampling cost can be reduced by grouping variables. Not only does the number of degrees of freedom increase, but also the rarely consumed units, such as 'Roaming MMS', lose influence over the estimated coefficients and cause fewer problems. All frequently consumed units' estimated prices remained overall stable with 40 or more degrees of freedom. Beyond 40 degrees of freedoms, even estimates for frequently consumed units become highly problematic.

I cannot offer an optimal sample size for hedonic price indexes in mobile communication, but there are some indicators for a lower boundary. Fifty observations per provider and period might be theoretically sufficient, but for official statistics, it is clearly not enough in my experience. Based on my work with this project, I do not think that anything beyond 100 degrees of freedom will result in reliable estimations. Even the 'large' sub-samples, with 200 or more estimations, may not be enough. As mentioned in the beginning, there is a trade-off between sample size and sampling cost. One way to eliminate sampling cost would be to sample bills directly from the providers, which could be possible for the government.

One should keep in mind that the underlying model puts contracts that are relatively expensive at a disadvantage. Therefore, poor customer consultation is punished by the index. Every provider is conscious of this, so they might deliver a biased sample. If a sample from providers is used, it is important to indicate precisely how bills are to be randomly selected. This could be done by giving the providers a set of phone numbers and months. In addition to the bills, information about phone discounts is needed, namely which phone was sold when and for how much. It seems very likely that providers have stored this information.

The consumers' age influences the implicit service prices and, consequently, the indexes. If the sample is large and the distribution of consumers similar among all providers, this problem is solved. If asymmetries among providers are present, one has to consider either the creation of indexes for different types of consumers or the application of a correction factor to the indexes.

Phone price discount and consumer survey

Regardless of where bills are sampled from, information about the phone discount is not included. Quite a bit of the sampling process has to do with obtaining the variables about the price of the phone sold by the provider and the date it was sold. I decided to embed the sampling of these two variables into a consumer survey with further questions about phone type, consumption behaviour and demographic variables.

However, the answers about price and purchase date are often estimates. Therefore, a precision indicator variable is added to the survey. As a result, most people indicated that they were certain about the price they paid. Difficulties occur when the purchase date is several years before. Firstly, people do not remember the date and price precisely. Secondly, it is difficult to elaborate the average market price of a phone from a purchase made a long time ago.

As an alternative to the market price at the purchase date, the current average market price could be used. The reasoning is that consumers pay a part of this discount back to the provider. Especially in contracts with a two-year minimal duration, the difference of the average market price between purchase date and the end of the contract can be huge.

Incomplete information, special and new services

Bills may not contain complete information. Firstly, scaling can be a problem, as we have seen. Variables can be adjusted, as shown for Orange minutes, but this is not desirable. Secondly, bills often do not contain any quantities, but these can be obtained through the consumers' online account. The quantities are provided by Swisscom up on request in the online account, but only for the past six months. Bills from some Sunrise contracts did not contain the data traffic used.

As mentioned in the data description, special services are excluded from the model and the corresponding estimations. Special services excluded are all services consumed from other companies, such as purchases over SMS or costly hot-lines. There are also contract specifications that directly affect the invoiced amount. Swisscom, for example, provides an additional discount for consumers who already have a contract for TV, internet and landline phones with them. These kinds of discounts were included in the analysis because they affect the price for the mobile communication services. One might argue that these discounts should be excluded because of 'fairness' across providers (not all of whom might provide landline services).

However, I think it is correct to implement these discounts, because they explicitly affect mobile communication prices, and not the prices of TV, internet or landline communication. Additionally, if these discounts were to be excluded, other discounts should also be excluded, such as those for students or young people. I think including all discounts from a provider that directly concern mobile communication prices is most consistent.

Finally, technical progress in mobile communication is relatively rapid. Units like SMS and MMS might disappear because all text communication may come to data traffic. Or new units might be introduced, such as very fast data traffic packages for a certain time period or amount. Units that are newly introduced during a period cannot be compared to older periods because these units did not exist then. Through chaining, this problem is partially resolved, and only the index between the period before and the period during the introduction of the new good is problematic. The most convenient way to handle this problem is to exclude this service from the introduction period and deduct its cost from the invoiced amount.

Chapter 3

Kilometer Price Index for Public Transport

In this chapter, a price index concept for public transport is presented. A modified Laspeyres index describes the price development of an averagely consumed kilometer. It is applied to Swiss Federal Railways data from 2007 to 2011.

After an introduction to Swiss public transport in section 3.1, the index is deducted in section 3.2 and illustrated through data in section 3.3. A conclusion follows in section 3.4. This chapter is the earliest part of the thesis, and it is based on Seger (2012).

3.1 Tariff plans in Swiss public transport

As noted by Brachinger (2011), price measurement in Swiss public transport does yield problems, due to tariff plans. When purchasing a single ticket for a train journey, the service or quantity consumed can be easily related to the price. Contrariwise, a very successful and often purchased ticket is the GA travelcard (Generalabonnement, abonnement général). The GA travelcard is a flat-rate tariff plan for all public transport for one person over a year. Consequently, the price of the GA is independent of consumption. There are other tariff plans that fall in between paying for every single ticket individually and purchasing a GA. The most popular one is the half-fare travelcard, which gives a 50% discount on every ticket purchased.

The Swiss Federal Railways (SBB, CFF) is the main provider on interregional routes. Regional routes are covered by local suppliers and tariff unions. These local suppliers and tariff unions usually follow the federal tariffs, but also offer additional options to pay for travelling. Several tariff plans or even tariff systems exist in Swiss public transport. In sum, for every route, different tariff plans can be used to pay the journey.

Specific scientific literature on public transport price indexes is difficult to find. In addition, providers do not communicate how they calculate or determine price changes. Even technical manuals from statistical offices do not contain public transport-specific information, and one has to rely on verbal explanations. As in both other chapters, either hedonic indexes or consumption profiles could be used to compare prices. The Swiss Federal Statistical Office (2011a) applies a method similar to consumption profiles in the formation of representative routes for the Swiss consumer price index (CPI).[6] Representative routes are not an optimal choice because a trip on a given route can be purchased under different tariff plans. Subsequently, the price for one route cannot be determined unambiguously. Hedonic price indexes, on the other hand, would certainly yield relatively precise price estimates for these tariff systems. However, the quality of the currently available data is not sufficient.

For public transport, a third possibility is chosen: measuring the price of a representative or average kilometer. The price for a kilometer is at first glance more like a characteristic number than an index. But in the end, it is based on possibly the most famous concept in price statistics; the Laspeyres price index. The method chosen has two advantages over others. Firstly, it uses data that are available and do not need to be sampled. Secondly, the method finally applied to describe the price development for an average or representative kilometer is plausible for a broad public and therefore easy to communicate. Most indexes or price communications in the press are not explained very well. In this project, index plausibility was a main target, also because it was

[6] In the manual cited above, no public transport-specific information is given. The information about how the Swiss Federal Statistical Office estimates public transport prices is based on verbal explanations. They are from a member of the office who is involved in the construction of public transport elementary price indexes for the Swiss CPI.

a joint project with Swiss Federal Railways. Consumers and politics should understand the measure, especially when it yields unexpected results, such as price decreases.

In section 3.2, the index concept is developed. Requirements of such an index are formulated and then the desired attributes are discussed. Two issues are important in this context. Firstly, multiple tariff plans offer different ways to pay for trips. Secondly, the effective consumption cannot be deducted from ticket sales because of the underlying tariff plans and their characteristics.

The concept is applied on data from the Swiss Federal Railways in section 3.3. An index that describes the implicit price development of an average kilometer travelled between 2007 and 2011 is developed. By adjusting price development to travelled kilometers, tariff increases are estimated to be systematically lower than they have been up to now. Additionally, in years without any official tariff change, changes in implicit prices can be observed. This happens because the implicit prices are not only dependent on the tariff, but also on consumption.

A summary follows in section 3.4.

3.2 Price index concept for an averagely travelled kilometer

In this section, the price index concept is presented. Firstly, in 3.2.1, the creation process is illustrated by summarising the requirements and desired attributes of the index. The results of this discussion are related to the Laspeyres price index concept, discussed in subsection 3.2.2. A formal description of the index is offered in 3.2.3.

3.2.1 Desired attributes of the index

The initial position in this joint project with the Swiss Federal Railways was to create a price index for passenger traffic. The Swiss Federal Railways specified neither a desired index concept nor a representation form. Therefore, first, the requirements that the index should suffice to are defined. Based on these requirements, the desired attributes of the index are deducted.

The requirements of the index are:

- Price development in public transport is frequently discussed in the media and politics. Consequently, the index should be comprehensible to the public. It should describe the price development of passenger traffic.
- The diversity of tariff plans in public transport is huge. Without further specifications, different types of tickets, and thus their prices, cannot be compared. Nevertheless, all ticket types, and especially their prices, must be included consistently.
- Public transport in Switzerland is faced with continuously increasing demand. The problem with standard price index formulas with constant spending shares is that they fail to identify actual consumption when tariff plans are present. In the case of a GA travelcard, for example, one GA sold does not indicate anything about how many journeys are made with it. A weighting scheme that represents actual consumption is required.
- Finally, quality changes over time should be included. The main changes are that transfers become faster and more comfortable trains are in use.

Based on the requirements stated above, the desired attributes of the index are defined as follows:

- Because of public interest, the resulting index should be easily comparable to the Swiss CPI. Consumers, politicians and the media should be able to compare public transport prices to general price development. The Swiss CPI is on the highest aggregation level a Laspeyres price index, see Swiss Federal Statistical Office (2011a). This concept is adapted for the public transport index.
- Ticket prices need to be implemented consistently. Because for some tickets, such as the GA, consumed distance and price paid are not related, kilometers are used as goods. Therefore, the implicit price per kilometer travelled (with a given ticket) is considered as price from now on, and not the explicit price paid for a ticket. Consequently, all prices

are normalised to kilometers and related to consumption.

- The index should describe the price development of an average trip and therefore represent all ticket types in proportion to their consumption. Therefore, as weights for each ticket type, it is not expenditure shares, as in standard Laspeyres indexes, but rather the proportion of kilometers travelled with the specific ticket type to total kilometers travelled. Note that a simple division of aggregated revenue by aggregated kilometers does not yield a useful result. Every price index has to compare the prices for a constant basket or consumption profile. Comparing prices of distinct baskets is the same as comparing the prices of apples and oranges.

- Quality changes must be included. Quality in public transport is influenced by various dimensions, such as safety, space available, hygiene in the toilets or food served. However, by far the most important aspect of quality is probably travel time.

Whereas quality can not generally be included in a Laspeyres-type index, travel time can be to some extent. The Swiss Federal Railways uses so-called 'tariff kilometers' in pricing. Basically, the price of a transfer from station A to B is, in the case of a single ticket, a linear transformation of the distance measured by 'geographical kilometers'. On most routes, tariff and geographical kilometers are identical. However, specific routes require major investments, like tunnels through the Alps or connections between cities. One possibility for providers to adjust the price on such specific routes is to increase the corresponding tariff kilometers artificially. The most famous Swiss example is Zurich-Berne, for which the tariff kilometers are significantly higher than the geographical ones. Therefore, if travel time is reduced and, as a result, quality increases on a route, tariff kilometers also increase. Aggregated tariff kilometers will be used to quantify consumption. By using tariff instead of geographical kilometers, partial quality adjustment is implemented.

3.2.2 Adjusting a Laspeyres price index to tariff plans

Based on the discussion in 3.2.1, an index similar to a Laspeyres price index can be created. For this purpose, the most important results from the discussion are summarised.

1. The scale of consumption is kilometers. Each kilometer is 'consumed' with a certain tariff plan or ticket type.
2. All prices are normalised to kilometers.
3. All kilometers consumed over a year constitute the consumption basket. The weights for the index are based on the corresponding distribution.
4. An immense number of different tickets and travelcards exist. Every single journey between two specific stations is an independent good. Therefore, tickets are classified by type and assigned to accounts, as described in 3.3.1.

As discussed in the previous subsection, the Laspeyres price index (3.1) is used as a basic framework. It is the most popular concept in price statistics, as seen in International Labour Office (2004), Fahrmeir et al. (2007) or Diewert, E. (2009). The Laspeyres index describes the price development of a basket of goods between two periods $t = 0, 1$. The change of price p of every good i from period 0 to 1 is weighted with the expenditure share s of this good. The expenditure share is the proportion of spendings for good i to total spendings for the basket, usually in $t = 0$.

$$P_{0,1} = \sum_{i=1}^{n} s_i^0 \cdot \frac{p_i^1}{p_i^0} \tag{3.1}$$

Kilometers are used as basic units and implicit prices per kilometer as prices. A ticket type i is a group of similar tickets. For each ticket type, monthly aggregated revenue and kilometers travelled are known. The implicit price per kilometer of a certain ticket type can therefore be determined for every month. As mentioned, using expenditure shares is a problem when multiple tariff plans are present. Therefore 'kilometer shares', instead of expenditure shares, are used. In the following subsection, the kilometer price index (KMI) is specified based on the Laspeyres concept.

3.2.3 The kilometer price index

Below, the KMI for public transport is formally specified. The Laspeyres index (3.1) is adjusted to the desired attributes stated in 3.2.2. The index to describe price development within a year is developed on a monthly basis. December of the previous year serves as the base period. All of the months of the year are compared to this base period.

First, the implicit price of a kilometer travelled with ticket type i at month t is defined as p_i^t. To determine this price, aggregated revenue r is divided by the aggregated number of kilometers km consumed with ticket type i at month t, as in equation (3.2).

$$p_i^t = \frac{r_i^t}{km_i^t} \tag{3.2}$$

As weight s for a ticket type i, the aggregated number of kilometers consumed in t relative to the total amount of kilometers consumed with all m ticket types is used, as shown in equation (3.3).

$$s_i^t = \frac{km_i^t}{\sum_{j=1}^{m} km_j^t} \tag{3.3}$$

The index is constructed on a monthly basis to describe price development over the course of a year. The question is which time period should serve as a basis for the weights. In the standard Laspeyres approach, the weights are determined in the base period, which would correspond to December of the previous year. Consumed kilometers underlie seasonal fluctuations, and the kilometer distribution might be different than the yearly distribution. Therefore, the yearly kilometer distribution is used to weight all twelve indexes within year y, as seen in equation (3.4).

$$s_i^y = \frac{km_i^y}{\sum_{j=1}^{m} km_j^y} \tag{3.4}$$

The KMI (3.5) describes the price development of an average kilometer over a year for each month (1). The base period (0) is the December of the previous year. The average kilometer is the proportional composition of all kilometers consumed in year y with all $m = n$ ticket types.

$$KMI_{0,1} = \sum_{i=1}^{n} \frac{km_i^y}{\sum_{j=1}^{m} km_j^y} \cdot \frac{\frac{r_i^1}{km_i^1}}{\frac{r_i^0}{km_i^0}} \tag{3.5}$$

Price development over one year is interesting, but price development over multiple years is much more relevant to the public discussion. To describe price development over multiple years, indexes can be chained (3.6). This involves a simple multiplication of two indexes, which is the same as multiplying growth factors. The point of time τ at which two indexes are chained can be every month. However, if all monthly indexes are constructed with the base of December of the previous year, τ will typically fall in December.

$$KMI_{0,1} = KMI_{0,\tau} \cdot KMI_{\tau,1} \tag{3.6}$$

If the base of the chained index must be changed, a base change can be carried out (3.7). This is done by dividing by the index with the same actual base period and the desired new base period $KMI_{0,\tau}$. Note that this is the same (rearranged) equation as for chaining (3.6).

$$KMI_{\tau,1} = \frac{KMI_{0,1}}{KMI_{0,\tau}} \tag{3.7}$$

The KMI describes the price development of an averagely travelled kilometer. Because it is chained over multiple years, the index is adjusted to changes in consumption behaviour. That is especially important because of the increasing demand. One minor disadvantage of chaining is that the price developments in different years are not weighted equally.

Note that the index is used to describe the price development of the Swiss Federal Railways over time, and not to compare different providers. A Laspeyres-type index is chosen because it can be interpreted straightforwardly. If different providers are compared, the same issues that arose with the hedonic price indexes for mobile communication will arise. Consumption may be dependent on tariff plans, and if it is, then only using the aggregated consumption of one provider as weights could yield biases. Also, using the aggregated number of kilometers travelled with both providers does not solve the problem, because one provider usually supplies more kilometers than the other. Consequently, this provider has more influence on the weights. Therefore, if several public transport providers are compared, one should think about using superlative indexes like Fisher or Törnqvist in order to treat all providers identically. An approach similar to the one illustrated at the end of subsection 2.2.3 could be applied. Indexes could be calculated to compare providers and then be chained over time periods, as in tables 2.1 and 2.2.

3.3 SBB passenger traffic price development

The development of a public transport price index was a joint project with the Swiss Federal Railways (SBB, CFF). This hinders a complete data description in 3.3.1 because data are partially confidential. Nevertheless, authorised results can be published, and the index, applied on SBB passenger traffic, will be presented in 3.3.2. Then, a comparison to other estimations for public transport price development is offered in subsection 3.3.3. The section closes with a close look at the two most important ticket types in the index, the 'GA travelcard' and the 'Normal tariff', in subsection 3.3.4.

3.3.1 Data

The KMI is based on revenues and kilometers per ticket type. Revenues per ticket type in particular are classified as confidential by the SBB, and so the raw data cannot be presented here. Revenues and kilometers are given from December 2006 to December 2011. Revenue is provided by the SBB accounting. The kilometer data are based on estimations and extrapolations made by the SBB, called 'Hochrechnung Personenverkehr', or abbreviated as 'HOP'. Due to changes in method, data before 2006 are not comparable without extensive modifications.

Seven ticket types are used to classify tickets. The most important types are 'GA travelcard' and 'Normal tariff'. It is important to note that in December 2010, more than half of the kilometers are travelled with a 'GA travelcard', and nearly 30% with the 'Normal tariff', which together make up most standard tickets in the Swiss railways. That more than half of the kilometers are purchased via GA, shows the importance to use implicit kilometer prices and effective consumption weights compared to expenditure shares. The major problem of the underlying ticket type classification is that first- and second-class tickets - which are clearly different products - are mixed in the accounts. As long as the ratio between kilometers consumed by both classes remains constant, there is no problem. But this is not a given and therefore in future projects, first and second class should get different accounts.

Finally, this index is based on data from the providers whose prices are compared. A price index is supposed to be 'objective' in every conceivable aspect, and treating every provider equally, but in this case it cannot be guaranteed. Consider this a first test of the method. Further applications should intensely analyse aggregation and sampling processes of the basic data. This is especially important if different providers and time periods are compared, to treat everyone identically and - if not possible - to make adjustments.

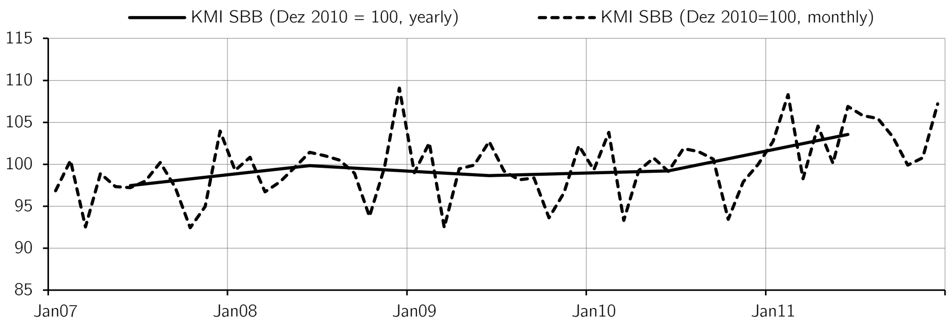
3.3.2 Price development from 2007 to 2011

In figure 3.1, the price development of the SBB passenger traffic is plotted. Both lines are KMI values with base period December 2010 equal to 100 points. The dashed line is the monthly index, and the solid line the yearly average index. The geometric mean is used to average the monthly values because price index values are growth factors. Applying the geometric mean instead of the arithmetic mean is more appropriate because the properties of the growth factors are maintained in the yearly values. The yearly averages are plotted in June and interpolated. Both lines are based on exactly the same basic index values.

It can be seen that the index is very volatile over different months. Usually there are two local minima and one local maximum per year. These have different reasons; for example, the SBB usually changes prices in December, and generally there is no commuting traffic during holidays. Moreover, the aggregation and especially differentiation in HOP also play a role.

Note that despite the fact that prices are only changed in December, notable monthly movements can be observed. This is due to the nature of the KMI.

Figure 3.1: SBB price development, 2007 - 2011



Note: The dashed line represents the monthly values of the KMI for the SBB passenger traffic with base period December 2010 equal to 100 points. The solid line is the yearly (geometric) means of the monthly KMI values. They are plotted in June and interpolated.

First and most importantly, consumption underlies seasonal fluctuations, which influence implicit prices per kilometer each month. Additionally, people may still travel with travelcards purchased before the price change, which also influences the price index. A third problem is in the data. The GA travelcard, for example, is sold on a specific date and is valid for one year. The revenue is put into the GA travelcard account. But in this account, the revenue is divided accordingly across all months. The SBB divides the revenue equally over all twelve months. This is obviously a simplification because a passenger does not travel an equal amount of kilometers every month. How revenue should be optimally distributed for the index is an open question.

The monthly index shows interesting elements of public transport pricing, but it also reveals unresolved problems, as discussed above. For this reason, index values are averaged over the year. In addition, yearly values can be compared to the CPI of the Swiss Federal Statistical Office (2012b) and the communicated price changes of the providers.

3.3.3 Comparison to tariff-based indexes

In Switzerland public transport can be split into two groups: direct traffic and regional traffic. Direct traffic includes roughly all interregional routes and is mainly covered by the SBB. Regional traffic is usually covered by different local providers. There are different tariff plans in every system. Usually, regional suppliers follow the tariffs of direct traffic, but they can and do deviate slightly. Though the SBB is the major supplier in direct traffic, it is not the only one. Price setting for direct traffic is supervised by the association for public transport, VöV (Verband öffentlicher Verkehr, Union des transports public). Therefore, all price changes are made and communicated by the VöV.

In Switzerland, two tariff plan-based measures for direct traffic prices exist thus far. Firstly, the VöV announces adjustments in tariffs, usually in December. Secondly, the Swiss Federal Statistical Office (2012b) has an elementary price index for direct traffic in the CPI. Whereas the VöV communication is done ex ante and therefore cannot be as precise, the CPI elementary index is measured afterwards, similar to the KMI developed in this analysis. Note that both other measures describe the development of explicit prices based on tickets resulting from tariff plans. Contrariwise, the KMI describes the implicit price development, based on actually consumed or travelled kilometers. The different measures are summarised in table 3.1. Note that the VöV, as well as the CPI, are for all direct traffic, whereas the KMI is only for the SBB. Because the SBB is the major provider in direct traffic and tariff plans are equal for all providers, this is a minor problem.

Table 3.1: SBB price development compared to prior year and CPI

	2008	2009	2010	2011	Total
KMI	2.45%	-1.21%	0.57%	4.40%	6.27%
VöV	3.00%	0.00%	0.00%	5.90%	9.08%
CPI direct traffic	3.49%	0.00%	0.00%	5.74%	9.43%
CPI total	2.43%	-0.48%	0.69%	0.23%	2.87%

Note: The table contains the yearly price development of the SBB passenger traffic compared to the previous year. The total development from 2007 to 2011 is added in the last column. The price development is measured by the kilometer price index (KMI), the VöV and the elementary price index for direct traffic of the Swiss CPI. To relate the SBB passenger traffic price development to general inflation, the 'CPI total' is added in the last row. Sources: Verbal SBB communications (VöV), Swiss Federal Statistical Office (2012b) (CPI) and own estimation (KMI).

Quite large differences can be observed. Whereas in the VöV communication and the CPI for direct traffic, no price change is measured in years without explicit tariff changes, the KMI shows movements in the implicit price. This is due to the nature of the KMI, as explained in previous sections and is to be expected. The following two major issues can be observed:

1. The KMI estimates explicit price increases (2008, 2011) as lower than both other measures.

2. In years without explicit tariff changes (2009, 2010), implicit prices change according to the KMI, particularly with a decrease in 2009.

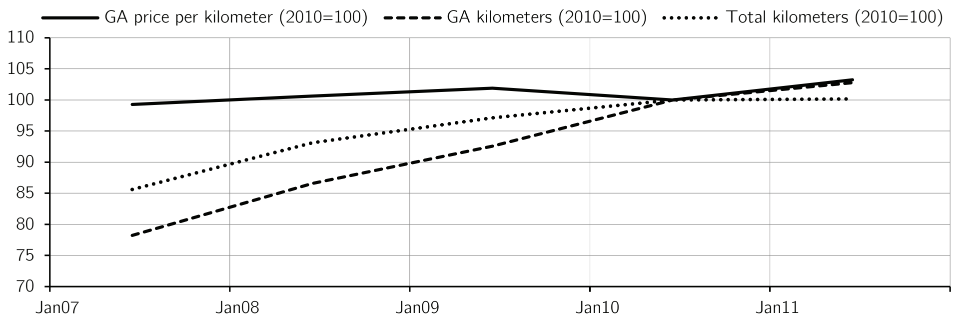
In addition, the KMI estimates the total price development between 2007 and 2011 at approximately 3% lower than in both other measures. If changes are compared to general price development in Switzerland (CPI total), only the last tariff change, from 2010 to 2011, differs significantly. Because this is a first encounter with this type of index in public transport, the results should be interpreted with caution. The presence of data aggregation issues cannot be fully denied. Additionally, remember that it is not exactly the same variables being compared (complete direct traffic versus SBB traffic). However, the notion that implicit prices can change despite the fact that tariffs have not been modified is important for price measurement in public transport, and it is not at all present in the public's perception.

3.3.4 The 'GA travelcard' and 'Normal tariff' ticket types

As mentioned in the data description, around 50% of all travelled kilometers are purchased via GA travelcard. Almost 30% are paid with a 'Normal tariff' ticket, which include all standard tickets and the half-fare travelcards. The remaining 20% of travelled kilometers are divided among five accounts that are not explicitly analysed here. In December 2010, the average price of a kilometer travelled with a GA travelcard was 0.094 CHF. The average price of a kilometer travelled with a 'Normal tariff' ticket was 0.211 CHF. The development of these unit prices, the corresponding consumption and their impact on the KMI are illustrated below.

The GA travelcard is the most important ticket type in the index. Additionally, it is a flat-rate tariff plan, and consumers can travel without restriction for a fixed amount. Figure 3.2 illustrates the implicit price per kilometer travelled with a GA travelcard. This is complemented by the amount of kilometers travelled with a GA travelcard and the total amount of kilometers travelled with any ticket type. All values are yearly arithmetic means. Due to the different scales (Swiss francs and kilometers) and magnitudes, all variables are normalised to 100 points in the year 2010.

Figure 3.2: The GA travelcard in the KMI



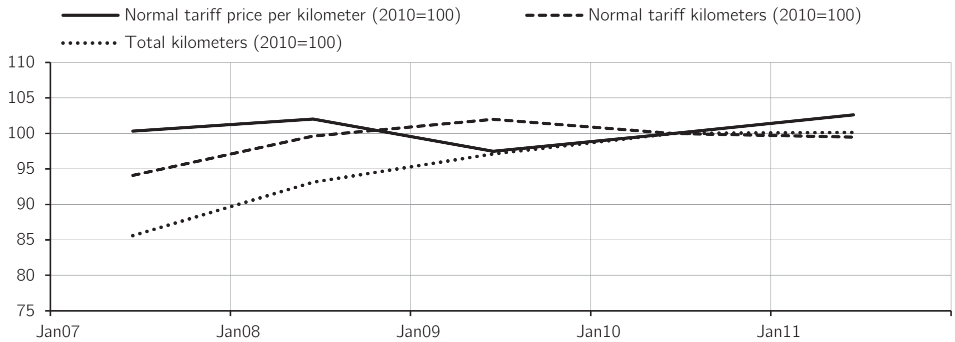
Note: The implicit price per kilometer of the GA travelcard (solid line) and the yearly amount of kilometers travelled with a GA travelcard (dashed line) are plotted. The total consumption or total amount of kilometers travelled with any ticket type is indicated by a third line (dotted). All values are normalised to 100 points in the year 2010.

First and most importantly, the implicit kilometer price of the GA increases by around 4% from 2007 to 2011. Therefore, the implicit price of the GA travelcard increased less than other ticket types. The average implicit price increase as measured by the KMI, is 6.27%, as seen in table 3.1. Despite the fact that the explicit prices of the GA travelcard increased significantly, the implicit price changed less. The aggregated number of kilometers travelled with a GA travelcard increased by approximately one-third from 2007 to 2011. This explains why the implicit kilometer price increased less than the explicit ticket price. Compared to the total consumption, the amount of travelled kilometers with the GA increased much more notably.

The implicit kilometer price of the GA is an important component of the results in this empirical section, and it explains, at least in part, why the implicit prices measured by the KMI differ from those resulting from the currently applied measures. All other ticket types have a weaker, but still significant impact on the KMI. The implicit kilometer prices of ticket types with small weights in particular increased more, such as the ones of 'Special offers' and 'Multi-trip tickets'. From the KMI perspective, the GA travelcard is the most successful tariff plan in Swiss public transport mainly because its average implicit kilometer price is much lower (and increases less rapidly) than those of other ticket types.

The 'Normal tariff' is the other important ticket type in the KMI. Figure 3.3 illustrates the implicit unit price, the amount of kilometers travelled with the normal tariff and the total amount of kilometers travelled with any ticket type. Because of the different scales and magnitudes, again all variables are normalised to 100 points in 2010. Recall that the implicit kilometer price of the normal tariff is about double that of the GA, and the amount of consumed kilometers is approximately 30% of total consumption.

Figure 3.3: The normal tariff tickets in the KMI



Note: The implicit price per kilometer of the 'Normal tariff' (solid line) and the yearly amount of kilometers travelled with a 'Normal tariff' ticket (dashed line) are plotted. The total consumption or total amount of kilometers travelled with any ticket type is indicated by a third line (dotted). All values are normalised to 100 points in the year 2010.

Significant differences between the 'Normal tariff' and 'GA travelcard' can be observed. The decrease in the KMI in 2009 can be explained by the normal tariff tickets, but not by the GA. From 2007 to 2011, the implicit kilometer price of the normal tariff increased by about 3%. It is not as much as with that of the GA, mostly because the explicit ticket prices increased less overall. Nevertheless, the absolute implicit kilometer price is still much higher. Consequently, the consumption of 'Normal tariff' kilometers increases less than the average, and even decreases in 2010 and 2011. Compared to the total consumption, the 'Normal tariff' kilometers are consumed less frequently, and their weight in the index is continuously decreasing over time.

As a result, the implicit prices for the GA travelcards and the normal tariff increased by 3% to 4% between 2007 and 2011. Of the kilometers travelled in total, 80% are paid with one of these two ticket types. As mentioned before, implicit kilometer prices for other, less frequently used ticket types increased significantly more. Possibly the most surprising result in this subsection is that the kilometers travelled with a GA travelcard increased a great deal, and those travelled with normal tariff tickets actually decreased in 2010 and 2011. This observation could be explained by implicit kilometer prices and explicit ticket prices. Consumers using a GA travelcard compensate for explicit price increases by raising their consumption or switching to another tariff plan (without the high fixed cost). Generally speaking, they minimise their 'personal' implicit kilometer prices. If a consumer travels frequently, the GA does minimise the implicit kilometer price. Contrariwise, consumers who use the normal tariff cannot substitute a less expensive tariff plan. Therefore, they have to pay for explicit price increases fully or travel less. Alternatively, they may consume more kilometers, switch into the GA tariff plan and benefit from low implicit kilometer prices. Consequently, the amount of kilometers travelled with the 'Normal tariff' decreases and the amount of those travelled with the 'GA travelcard' increases.

3.4 Summary

The KMI describes the price development of an average kilometer. The concept chosen to illustrate the price development of an average kilometer is clear, comprehensible and therefore easy to communicate.

By using implicit kilometer prices, the index reflects the prices of actual consumption and not explicit prices of tariff plans. All ticket types are included identically in the index. Through the use of tariff instead of geographical kilometers, the index is partially adjusted for quality. The major disadvantage of the index concept is, first, that the construction is dependent on aggregated data and second, these data are supplied by the providers themselves. Therefore complete independence between price measurement and providers cannot be claimed.

The price development of the SBB passenger traffic measured by the KMI is as expected. It is shown that price increases have been measured and communicated relatively high (in comparison to the KMI). The KMI reflects the implicit price development in public transport, while the other indexes describe explicit prices for tickets what causes this difference. The implicit price also changes without modification of the tariff plans because it is dependent on the consumption of kilometers. In one year without tariff plan modification, the implicit price actually falls. The most important ticket type in the index is the GA travelcard. It is a special flat-rate tariff plan that is partially responsible for the lower implicit prices. The consumption of kilometers using a GA travelcard increases consistently in absolute values, but also relative to other ticket types. Consequently, the implicit kilometer price of the GA travelcard increases less than any of the other ticket types. Consumers using normal tariff tickets, in contrast, pay explicit price modifications fully, cannot substitute cheaper tariff plans and therefore consume relatively fewer kilometers. The implicit price development of the SBB passenger traffic from 2007 to 2010 is similar to general price development in Switzerland, which is measured by the CPI. In 2011, it is clearly stronger.

Further applications of this method should mainly invest in a better data structure. First- and second-class tickets should not be mixed in the accounts. Moreover, if the concept is applied to compare multiple providers, time and account differentiations have to be identical for all participating providers. The key advantage of this index is that the data are available. The problem is the dependence of the providers, which is rather unlucky from the consumer's perspective. In the consumer's perspective, a hedonic index is preferable, if the data quality is sufficient. However, so far, this is the most accurate approach to measure price development in public transport. The notion that implicit prices can also change without any tariff modification - therefore change dynamically, depending on consumption - is a major gain of this analysis, and, motivated the entire thesis.

Chapter 4

Administered Prices of Basic Services in Swiss Municipalities

Service prices for electricity, waste management, water supply and sewer water in Swiss municipalities are analysed in chapter 4.

Section 4.1 is an introduction to basic service prices in Switzerland. The index concept to measure and compare service price levels across the 324 largest Swiss municipalities is explained in section 4.2. The estimated price levels, especially the differences, are discussed with regard to several municipality characteristics in section 4.3. For this purpose, the prices are related to economies of scale, income tax rates, rents, institutional controls and capitalisation. A summary and outlook follow in section 4.4.

4.1 Introduction to administered prices of basic services

Service prices for electricity, water supply, sewer water and waste management are paid by every Swiss household at least once a year. Unlike with mobile communication and public transport, service providers are almost always local monopolists and offer only one single tariff plan within a municipality. Consequently, consumers can not substitute services, providers or tariff plans. A two-person household in one of the 324 largest Swiss municipalities pays on average about 600 Swiss francs for electricity and 200 Swiss francs for each of the other three services per year.

Besides the considerable yearly cost for every household, the prices for these basic services have three characteristics that motivate an analysis. First and most importantly, the services are supplied by local monopolistic providers. In addition, the service prices are administered by local governments. Consequently, these prices are not the result of supply and demand in a competitive market and should therefore be monitored closely. Secondly, administered prices for basic services are related to user charges. User charges contribute a considerable part of municipalities' revenue. By analysing basic service prices, the direct impact of user charges (which are contained in the prices) on households can be illustrated. Finally, a monopolistic provider offers only one tariff plan in a municipality. This allows the implementation of consumption profiles with considerably fewer problems than if multiple tariff plans per service, provider and municipality were in place. In this case, the profiles represent the consumption of typical Swiss household types. The prices are representative because they can be determined unambiguously for every household. Consequently, they can be compared consistently via consumption profiles.

Monopolistic supply, administered service prices and user charges

Basic services on a communal or municipal level are supplied in most cases by monopolists. In some cases, the local government produces the service. In others, a semi-private firm is a supplier in which municipalities or cantons have property rights. A third possibility is that governments designate a private firm to be a monopolistic supplier.

In Switzerland, governments on a communal, cantonal or federal level set prices and impose user charges. These prices are considered administered. Many different prices at all levels are administered, as can be seen in the report from the Swiss Price Control (2005). This also holds for all four basic service prices analysed in this chapter. The administered price of a basic service is dependent upon the consumed service units and the underlying tariff plan. The tariff plan transforms consumed units into the explicit service price. The administered, explicit service price corresponds to the total service cost for a household.

According to the federal constitution of the Swiss confederation, user charges (and consequently administered prices) underlie two principles: the cost recovery principle and the benefits principle. The cost recovery principle urges governments not to let revenues exceed costs for services financed by user charges. This balance is often very difficult to maintain. Courts normally do not pursue imbalances, except in the case of very large exaggerations, as mentioned by Jaeger et al. (2002). The benefits principle states that consumers must not pay for more than they effectively consume. With regard to both principles, the observed variation of administered prices, illustrated in section 4.2, is not expected.

The household perspective on non-tax government revenue

Governments generate a major part of their revenue through taxes. A smaller proportion of this, Feld et al. (2003) estimate around 20% at the total and communal levels, are generated by user charges. Jaeger et al. (2002) estimate the overall non-tax revenue at 25.6%, and at the communal level, they estimate that this reaches 35.7%. The inventory of the Swiss Price Control (2005) supports these claims; municipalities in particular tend to show a high proportion of non-tax revenue. Although government revenue is not the major object of interest in this analysis, these numbers show that user charges can be an important part of this revenue, especially in municipalities.

User charges are analysed in the international literature (which is not explicitly mentioned here), but mostly as aggregated revenue. Likewise, in the Swiss literature, which is discussed throughout the chapter, user charges are predominantly introduced as aggregated government revenue. The problem with aggregated revenue is that the data are provided by the government. It is often unclear as to how households are really affected. The reason is that households do not only pay user charges. User charges are, as discussed before, merely one part of the overall cost for a service. A simple division of generated revenue per service by population size does not necessarily yield a consistent estimator for the burden on households.

Administered prices for basic (government) services are rarely analysed in the public economics literature. Most standard textbooks contain zero to maximally two pages about user charges. They never discuss administered prices; see, for example, Persson and Tabellini (2000), Mueller (2003) or Blankart (2012). An exception to this rule is a study about administered service prices paid by Swiss households by Pommerehne (1983). He pursues the question in an analysis about 100 cities, whether private or public waste management has lower prices and production costs.

The main benefit of comparing service prices instead of aggregated revenue is that the direct impact on households can be analysed. Although an alternative view on the impacts of government revenue is provided, a direct inference on government revenue is not possible. User charges that generate government revenue are merely one part of administered prices, dependent on the specific service, provider and municipality. Additionally, statements about production efficiency through price comparisons may be biased because service qualities differ across municipalities. However, if it is assumed that services have similar levels of quality, then the price is a much stronger indicator of (in-)efficiency than a comparison of aggregated cost and revenue of services.

Measuring basic service prices using consumption profiles

In 2008, the Swiss national council was faced with a motion[7] that requested a detailed analysis of the user charge burden on households. The four services analysed in this study constitute a considerable part of these costs. However, due to the enormous number of very distinct user charges, the motion could not be satisfied. The Federal Finance Administration (2012) published a concept paper as a response to discover whether the cost recovery principle was respected. They compare aggregated cost and revenue for services, but they do not make a statement about the user charge burden of households, nor do they discuss the benefits principle. Therefore, they do not answer the motion. The Swiss price control began gathering data some years ago about administered service prices in municipalities, namely for waste management, sewer water and water supply. They determine prices for three household types with

[7] A motion is a proposal to a parliament made by a member of the parliament. It can be made in a communal, cantonal or federal parliament.

corresponding consumption profiles. Additionally, the Swiss electricity commission maintains a similar database of electricity prices.

Unlike scientists, politicians are interested in administered service prices as described above. Through its different institutions, the government is monitoring the prices households face. Nevertheless, observing the overall user charge burden for Swiss households is an extremely complex task. At the very least, it requires an immense effort, as will be discussed in more detail in section 4.2.

For this analysis, an index based on consumption profiles is used. In the general introduction, several problems of consumption profiles were discussed. Here, consumption profiles are used for several reasons. First, the most severe problem with consumption profiles is not present. In this case, a provider only offers one tariff plan per municipality, and there is only one provider per municipality. Thus, no assumptions about perfectly informed and rational consumers have to be made in order to select a tariff plan. The other problems are to some extent still present, but they can be resolved in a satisfying manner. However, the use of profiles also has a practical motivation. Consider that it is not just a few service providers that are compared. Prices are administered individually in each of the 324 municipalities. A representative random sample for each municipality, as in the mobile communication project in chapter 2, would create an exorbitant cost. Using a similar approach as the price index for public transport in chapter 3 poses a problem because aggregated revenue from user charges does not necessarily reflect the prices households pay. Whether comparable aggregates for revenue and especially consumed units over all municipalities even exist is an open question. In sum, using consumption profiles for households is not the most elegant solution, but in this case, it is the best feasible solution.

In section 4.2, based on household consumption profiles, a price index for basic services in municipalities is constructed. Criteria are defined in order to select all important basic services. Based on these criteria, electricity, water supply, sewer water and waste management are included in indexes for administered basic service prices in municipalities. The distribution of these administered prices across the 324 largest Swiss municipalities is analysed descriptively. The data used are relatively new, and they have not yet been analysed jointly. As a first result, quite large intra- and inter-cantonal differences in price levels can be observed. Considering that all services are quite similar across municipalities and that the benefits and cost recovery principles should be respected, these differences come as a surprise.

In section 4.3, an attempt is made to explain the service price differences through several characteristics of the municipalities. Firstly, it is shown that there is no indication of economies of scale. The administered prices are independent of a municipalities population and agglomeration size. Secondly, the relation between tax rates, rents and administered price levels is illustrated. Municipalities with high income tax rates show relatively high service price levels. Subsequently, the influence of fiscal control on price levels is investigated. In municipalities with potentially strong finance commissions, administered prices tend to be relatively low. Finally, the impact of administered prices on municipalities is discussed by analysing the capitalisation of service prices into rents. Administered prices do not seem to capitalise. A summary and outlook follow in section 4.4.

4.2 Price index concept for Swiss municipalities

The result of this section is an index for administered prices (API) of basic services across the 324 largest Swiss municipalities. The index serves to measure and analyse these administered prices for basic services in this section. It will be used as an endogenous variable in section 4.3 for further analyses. The index is presented in detail in table A.12 in the appendix. Summary statistics are reported in table 4.2.

The index measures how much a representative Swiss household pays in a given municipality for electricity, waste management, water supply and sewer water services per year. First, in subsection 4.2.1, the selection criteria for the services to be included in the index to compare municipalities are defined. In 4.2.2, the standard households and corresponding consumption profiles are presented. These are used to estimate average service prices. Finally, in 4.2.3, the administered price index for Swiss municipalities is formally described, empirically presented and interpreted.

4.2.1 Selection and description of services

On all three levels of state - federal, cantonal and communal - governments supply different services to their citizens. In the federal Swiss state, many legal differences throughout cantons and municipalities lead to different service structures, tariff plans and prices. The resulting administered prices can be characterised as follows:

- They may differ greatly. Whereas prices for health care, for example, can be extraordinarily high, an attestation from an administrative office costs a few Swiss francs.
- Prices are administered on a federal, cantonal or communal level.
- Prices may be directly regulated, be the result of a (state-) monopoly or fiscally influenced by special taxes, see Price Control (2005).
- The frequency of purchases differs widely across households. Some services are consumed daily and paid for at least once a year, like water supply. Others may never even be incurred, such as charges for civil weddings.

Including all (administered) prices of a municipality consistently in an index is a complex problem because of the varying service characteristics. From a household perspective, it is very difficult to include the prices of a birth certificate and water supply in the same index, as long as effectively observed purchasing frequencies with joint frequency distributions are used. First, the joint frequency distributions are often unknown. Second, the profiles would be extremely complex and specific. A profile should represent a typical consumption pattern. If a lot of services are included, the profiles become overly specific and are not able to represent a typical household. Therefore, criteria are defined in order to be able to include the most 'important' services in a consistent manner.

Stating selection criteria obviously excludes part of the reality, but this is, as discussed, required. The statistical benefit of the criteria listed below is that the construction cost of the index is minimised, but the most important services are still included. The following criteria describe the characteristics of what is understood as an important service, assuring that it will be included:

- A relevant amount of direct spending of every household is covered.
- All services are consumed (or purchased) at least once a year by every household.
- The quality of each service is approximately equal across all municipalities.
- Substitution of different services or services of other municipalities is not possible. For example, the water supply service of a municipality can not be replaced either by another service nor by the water supply service of another municipality.

Applying these criteria to the inventory of administered prices of the Swiss Price Control (2005) leads to the selection of the following four services: water supply, sewer water, waste management and electricity supply. This selection covers the most 'expensive' and frequently purchased services with administered prices on a communal level. Note that on a federal level, radio and television charges would also fit to these criteria. On a cantonal level, for a lot of households, education and health care costs are relevant and frequent spendings. However, the index only includes basic service prices that are administered on a communal level. Thus, radio and television, education and health care prices are not considered. The four services that will be analysed are described briefly below.

Water supply is usually organised by every municipality on its own. Sewer water services are often supplied jointly by multiple municipalities (for topographical reasons). Every household receives a bill at least once a year. Tenants pay additional expenses on top of the rent, and these are invoiced separately by the renter (who receives a bill from the supplier). When a house is constructed, a connection fee for access to the water network has to be paid. The amount is specified individually in municipalities. These connection fees, which compensate the municipalities for investments in the infrastructure (in this case, for creating a connection between the house and the municipalities' water supply network), are not considered here. First, they are not included because they are implemented differently across different municipalities, and so far it is not possible to treat them consistently. Secondly, all investments in a building are usually passed to the tenants via rents. The rents are used as a control variable in the empirical analysis in section 4.3.

Waste management is typically organised into joint waste management authorities by several municipalities or whole cantons, including collection and elimination. In most municipalities, households pay a fee for every waste bag (by purchasing it). Some communities, especially in the French-speaking part, do not yet impose fees on waste bags. They were urged by the Swiss Federal Tribunal to implement this as soon as possible due to the cost recovery principle. Additionally, a basic yearly fee can be charged. For special waste, pricing schemes vary widely. This analysis focuses exclusively on standard household waste.

In most areas, the electricity supply is covered by one provider across several cantons, but not necessarily. The largest proportion of the Swiss electricity market is supplied by a few firms. Nonetheless, prices from the same supplier may differ in different cantons and municipalities due to different contracts or user charges on a communal level. Some municipalities have up to four electricity suppliers, but households usually cannot not choose their supplier. The supplier is defined by the address of the household.

This selection of services allows the comparison of the most important service prices in municipalities in a consistent manner because they adhere to the four criteria introduced above. Note that these services are not necessarily provided by the governments themselves, so inferences regarding government revenue are not entirely valid. If the criteria were relaxed, other services may also be included in the basket. The most important criterion for keeping the index creation efficient is the inclusion of only services with a relatively high yearly expenditure share. A service that is purchased on average once every 20 years and costs a few Swiss francs does not change the index significantly, but it may complicate its construction drastically. Theoretically, the major issue with including other services is the extension of consumption profiles. This results in overly specific profiles, as discussed earlier.

4.2.2 Households, consumption profiles and service prices

Standard households are introduced due to tariff plans, which do not allow a simple multiplication of quantity and unit prices. Different household consumption profiles allow the measurement of prices for different consumption intensities. As a result, the Swiss price control gathered prices for three standard households. Prices are given for the 324 largest Swiss municipalities, with at least 5′000 inhabitants in 2012. The prices for waste management, water supply and sewer water are from the Swiss Price Control (2012). They began building the database around 2010 and completed it 2012, so no complete panel was available in 2012, when this project was carried out. The data are complemented by electricity prices provided by the Federal Electricity Comission (2012).

For all four services, the prices for three standard households with a specific yearly consumption profile, as seen in table 4.1, are given. The consumption profiles and the household types are based on the collaborative efforts of the Federal Statistical Office and the price control. Electricity consumption is estimated by the electricity commission and then matched for this study to the household profiles. The most frequent household types, apart from the two-person household, are included.

Table 4.1: Standard households and consumption profiles

Characteristics	Persons	Rooms	Type	Living m^2	Floors
Household 1	1	2	Apartm.	55	5
Household 2	3	4	Apartm.	100	3
Household 3	4	6	House	150	2
Consumption	Waste 35l-bag	Waste 60l-bag	Waste kg	Water m^3	Electricity kWh
Household 1	41	3	229	60	1’600
Household 2	122	9	681	170	2’500
Household 3	162	12	904	230	10’000

Sources: Price Control (2012), Federal Electricity Comission (2012)

As previously mentioned, prices are observed for every household type and every municipality. The prices were measured by determining how much a given household type, as described in the upper half of the table, in a certain municipality had to pay for its yearly usage of a service, as indicated in the second half of the table. In the basic data for every service, corresponding household and municipality, one price is included, rendering a total of 3′888 prices. Sewer water estimations are complemented by building size for rain water. The genuine consumption profiles contain more details; this is a summary of the most important characteristics.

In order to obtain one single price $p_{i,j}$ for every service i in a municipality j, a weighted average price over all three standard households is estimated as stated in equation (4.1). The weight w_h for household type h is based on the frequency distribution of households in municipalities, see Swiss Federal Statistical Office (2011b).

$$p_{i,j} = \sum_{h=1}^{3} w_h \cdot p_{h,i,j} \tag{4.1}$$

The weights used are: household type 1: 0.50; household type 2: 0.30; and household type 3: 0.20. The relative frequency of the two-person household is equally distributed between the weights of household types 1 and 2. The weight of household type 3 is the sum of the relative frequencies of households containing four or more persons. In the 324 municipalities, an average of about 2.3 persons were living in one household. The weights do not change significantly if the household distributions of all other Swiss municipalities are added.

The weights used in the average service price in equation (4.1), are the same for every municipality, despite the fact that frequency distributions of household sizes differ among municipalities. The constructed mean price measures what a representative Swiss household in municipality j pays for service i. If the household distribution of each municipality were to be used as weights, prices could not be compared. The underlying basket would change for each municipality, and prices for differently aggregated consumption profiles would be compared.

A description and interpretation of the price distributions, summarised in table 4.2, follows in the next subsection, combined with the discussion of the indexes. The frequency distributions of all service prices are plotted in the appendix in figure A.2.2. A detailed list of prices from all municipalities is in table A.12, also in the appendix. Note that prices are indexed to 100 points and not scaled in Swiss francs.

Introducing standard households and consumption profiles allows us to compare service prices across municipalities. Using consumption profiles is a huge simplification of the reality. A large random sample of household consumption and invoiced amounts would be much better, but also drastically more expensive to create. Random sampling would improve the indexes because the 'true' consumption distribution could be estimated. Based on such a 'true' consumption distribution, prices would be estimated for the effectively consumed service units and not hypothetical consumption profiles (even though these are based on estimations of consumption). Additionally, those parts of consumption that are not included in predefined consumption profiles, mainly connection fees for access to different networks of water or electricity supply, could be included. Special types of waste management charges could be added as well, which is nearly impossible with profiles.

4.2.3 Administered price index for basic services

The administered price index (API) in equation (4.2) describes the price for the yearly consumption of an average Swiss household for all selected services in municipality j. The service prices $p_{h,i,j}$ are weighted according to its households relative frequency w_h as before, and then aggregated over all four services i. This is the basic administered price index that will be used later on. It can be slightly modified, depending on the analyses and underlying models.

$$API_j = \sum_{i=1}^{4} \sum_{h=1}^{3} w_h \cdot p_{h,i,j} \tag{4.2}$$

The API as defined in (4.2) is an average price. In order to obtain an index value, every API-value is divided by the arithmetic mean of all municipalities and multiplied by 100. Therefore, the mean across all municipalities is 100 points. Table 4.2 illustrates the summary statistics of the API, the API without electricity (API$_{-e}$) and the average prices for the four single goods as defined in the previous subsection. The complete index lists are shown in table A.12 in the appendix.

The mean price of electricity (for a 2.3-person household, which is the average household size in this sample) is about 610 Swiss francs (CHF), whereas the means of the other three prices are slightly above 200 CHF. Electricity, therefore, generates half of the cost in the selected basket. Additionally, electricity is supplied by larger firms over larger regions than the other services. Thus, the API without electricity (API$_{-e}$) is introduced as an additional index with

Table 4.2: Summary statistics for the API 2012

Variable		Scale	Mean	SD	Min	Max
Administered Price Index	API	Index	100.0	13.7	61.6	151.7
API without electricity	API_{-e}	Index	100.0	23.7	38.4	179.6
Electricity	EL	CHF	609.9	75.5	398.0	827.2
Waste management	WM	CHF	214.8	91.2	0.0	382.9
Sewer water	SW	CHF	235.9	89.4	57.3	502.4
Water supply	WS	CHF	219.3	81.9	0.0	624.4

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

approximately equally expensive services.

The most 'expensive' municipality in the API is Le Locle, with an index value of 151.72. It is more than twice as expensive as Lugano, with 61.56 points on rank one. This difference, which is even larger in the API without electricity, is quite surprising, keeping in mind that the services are similar, and cost recovery and benefits principles should be respected. The standard deviation of the API is 13.67 points, implying that a large number of municipalities range between 80 and 120 points and show quite similar prices.

Four municipalities have a price equal to zero in water supply and 39 in waste management. The waste management price is predominantly zero in municipalities in the French-speaking part because no charges are placed on waste bags. The reasons for water prices being equal to zero are usually special property rights and billing procedures. Before closing section 4.2, two issues should be described. First, the conditional distribution of administered prices in cantons is illustrated. Then, the correlation between the different service prices across municipalities is analysed.

Although the municipalities can set prices autonomously, regional providers and cantonal regulations have an influence. Figure 4.1 shows the API-distribution over cantons. The box plots for small cantons with a few or even just one municipality containing 5′000 or more inhabitants have no minimal or maximal values. In cantons with only one large municipality, only the median is shown. Dots indicate outliers.

Quite large intra- and inter-cantonal deviations can be observed. While the medians remain between 80 and 120 points for all cantons, the maximum span

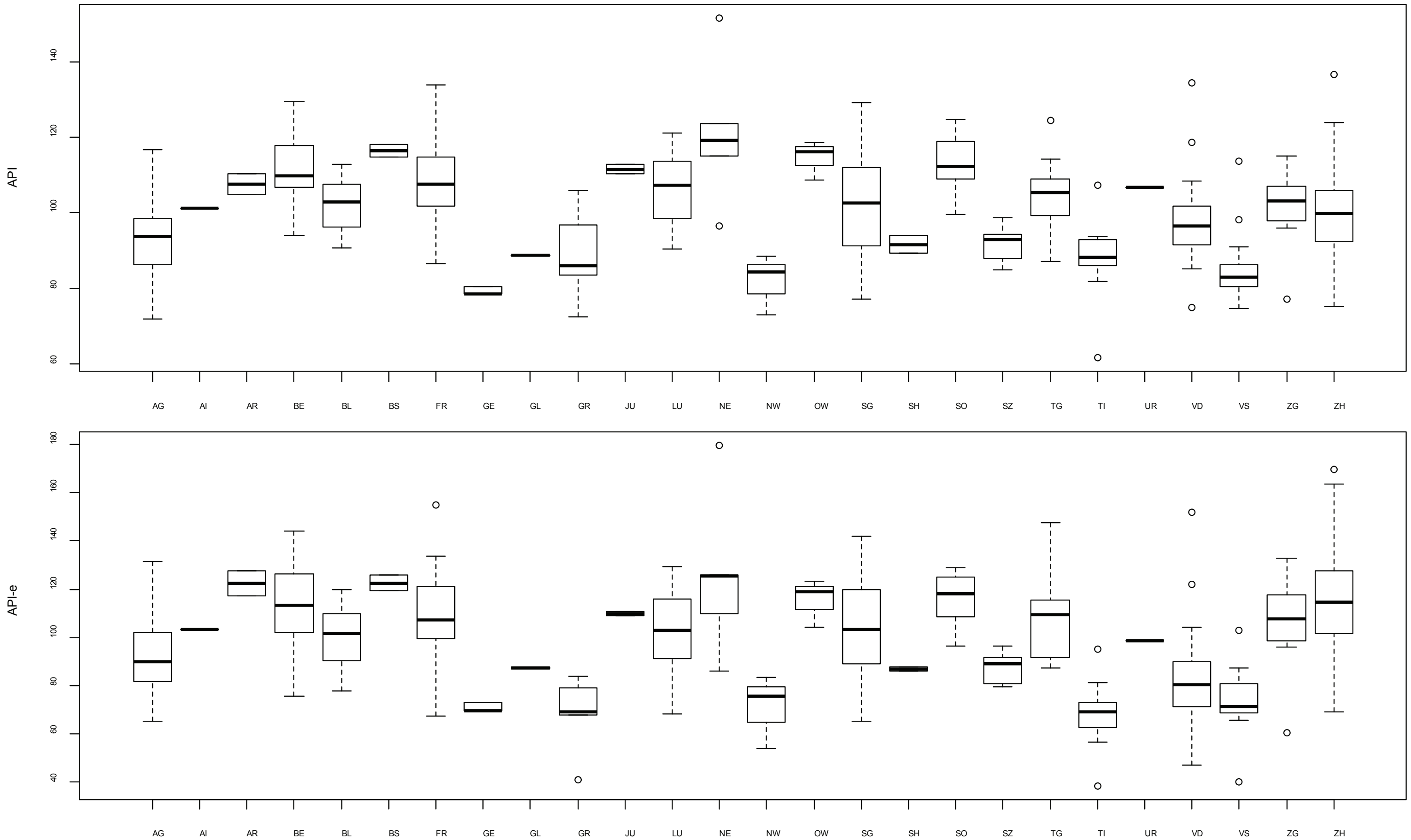


Figure 4.1: API distribution within and across cantons. The API and API$_{-e}$ distribution for every canton is plotted by box-plots. The bold bar indicates the median of every canton, the boxes the interquartile range, dashed lines indicate first and fourth quartile and points outliers. Very small cantons, such as Glarus (GL), have only one municipality with 5'000 or more inhabitants, hence only the median is plotted. In small cantons with only few large municipalities, the box captures all observations. In Geneva (GE), all prices are administered on nearly identical levels and plotted in a box.

in a canton may be larger than 40 points. If the observations between the 25% and 75% quartiles of each canton are considered, some cantons show clearly higher overall prices than others. As already indicated in table 4.2, the span width increases in the API without electricity. The cantonal distributions of single service prices are in figure A.2 in the appendix.

Finally, in general, for all four services, are municipalities expensive or cheap? In other words, do prices for different services correlate across municipalities? Table 4.3 shows correlations between the administered service prices for the entire data set and a restricted sample (without any municipality showing any price equal to zero).

Table 4.3: Correlations between service prices

		EL	WM	SW	WS
Electricity	EL	–	−0.08	0.09	−0.02
Waste management	WM	−0.13*	–	0.11*	−0.19***
Sewer water	SW	0.08	0.03	–	0.22***
Water supply	WS	0.00	0.01	0.30***	–

The correlations are estimated by Bravais-Pearson correlation coefficients. The X-squared statistics significance levels are: 0 '***' 0.001 '**' 0.01 '*' 0.05. The restricted sample without municipalities with waste management or water supply prices equal to zero is on the left-hand, lower half, with sample size of n=281. The entire sample is on the right-hand, upper half with, n=324 observations.

The only correlation that is significantly positive (at 5%) in both samples is the one between water supply and sewer water. This observation seems quite plausible, even though water supply is usually run by a municipality on its own, while sewer water tends to be run by multiple municipalities. Waste management prices correlate significantly negatively with electricity in the restricted sample (without all municipalities showing any price equal to zero) and with water supply in the complete sample. A significant positive correlation of waste management and sewer water prices can be observed in the complete sample, but not the restricted one. With the exception of water supply and sewer water, prices correlate neither strongly nor systematically.

The small descriptive analysis at the end of this section shows that administered service prices vary within and among cantons. With the exception of water supply and sewer water service prices, they do not correlate significantly. Keep in mind that in general, high administered prices are not necessarily bad. The cost recovery and benefits principle should be respected. For example, a lot of municipalities have a waste management price equal to zero, and they will be forced to change it in near future. This implementation will change the API significantly and lower its standard deviation. Additionally, service quality might vary, which could partly explain differences - but it does not necessarily have to.

4.3 Empirical analyses of administered prices

The API index of section 4.2 indicates that there are price level differences between municipalities. In this section, the price differences are analysed with regard to different municipality characteristics. Four independent analyses are carried out. The aim of this section is thus to illustrate different possible aspects to explain administered price levels; therefore, the analyses are split in four parts. The fact that a large number of explanatory variables is included is the second reason not only to create one model that explains all aspects jointly, but to split the analyses. Finally, note that the underlying sample consists only of the 324 largest Swiss municipalities. The results of this section are therefore valid for Swiss municipalities with more than 5′000 inhabitants.

In the first subsection, 4.3.1, the data used to describe municipality characteristics is presented. Then, whether the prices of basic services benefit from economies of scale is investigated in 4.3.2. In 4.3.3, the relation between administered price levels, income tax burden and rents is highlighted. After discussing the influence of scale effects, tax burden and rents on administered price levels, in 4.3.4 how the prices are affected by institutional control is analysed. The section is concluded in subsection 4.3.5 with the analysis of the effect of administered prices on municipalities via capitalisation.

4.3.1 Data

Some characteristics of the data was described in subsection 4.2.3, mainly the administered price index (API), the API without electricity (API_{-e}) and the prices for single services. In this subsection, all characteristic variables of municipalities are explained. They are summarised in table 4.4. For the 324 municipalities, different categories of variables are used. The table is divided according to these categories. All data used, except the construction variables and the household distribution in the 'Tax' variable, are for the same year as the service prices, i.e. 2012.

Municipality, topography, language and region

The first set of variables describes mainly geographical, economic, cultural and demographic characteristics of municipalities. The combination of these particular variables allows us to describe a municipality precisely.

'Municipality' contains seven binary dummies, which yield information mainly about location and economic structure. Every municipality is assigned to one type and therefore cannot belong to multiple types. The characteristics are 'Centre', 'Suburban', 'High-income', 'Peri-urban', 'Tourist', 'Industrial' and 'Agronomic'.

'Topography' has four characteristics, namely 'Midland', 'Alps' and 'Jura', which corresponds to the basic geographical repartition of Switzerland. The fourth characteristics is 'non-assignable', used for a few observations. Whereas most area is covered by the Alps, most municipalities with 5′000 inhabitants or more are located in the Midland. The region with the smallest number of municipalities, and with the smallest area, is the Jura.

'Language' is dived into 'German', 'French' and 'Italian'. Even though with Rhaeto-Romanic, a fourth language is spoken in Switzerland, no municipality in the sample has it as an official language. German is spoken in 249 municipalities, French in 66 and Italian in 9.

Finally, for 'Region', Switzerland can be divided into seven principle parts, namely 'Région lémanique', 'Espace Midland', 'North-west', 'Zurich', 'East', 'Central' and 'Ticino'. The regions are used to control for local effects more precisely than with language or topography dummies.[8]

[8]However, using cantons directly would be even better. But because only 324 municipalities are distributed over 26 cantons, econometric issues arise. The main problem is that some cantons only have one municipality in the sample. This causes problems in the estimation of coefficients (the design matrix sometimes cannot be inverted). Cantonal effects

Table 4.4: Explanatory variables for municipalities in 2012

Variable	Description	Mean	SD	Min	Max	Source
Municipality	Seven dummies describing the geographic and economic structure					Swiss Federal Statistical Office (2012a)
Topography	Four dummies describing the topographical location					Swiss Federal Statistical Office (2012a)
Language	Three dummies describing the official language					Swiss Federal Statistical Office (2012a)
Region	Seven dummies describing the geographical region					Swiss Federal Statistical Office (2012a)
Agglomeration	Index describing the agglomeration size	4.41	2	1	7	Swiss Federal Statistical Office (2012a)
Population	Population size	14'570	26'997	5'051	368'700	Price Control (2012)
Tax	Index of average communal and cantonal income tax burden	100	19.96	39.64	157.1	Swiss Federal Statistical Office (2012d)
Rent	Index of average rent for a 4.5-room apartment	100	24.09	57.25	195.1	comparis.ch (2012)
Parliament	Dummy for municipalities with parliament (vs. town meeting)	0.432	0.495	0	1	Ladner (2012), idheap, University of Lausanne
Finance commission index	Index of strength of communal finance commission	1.7	0.92	0	3	Rühli (2012), Avenir Suisse
Finance commission dummies	Four dummies on elements of finance commissions					Rühli (2012), Avenir Suisse
Constructions finished	Constructions finished in 2010 and 2011	154.4	245.87	0	3'512	Swiss Federal Statistical Office (2012c)
Building applications	Building applications accepted in 2010 and 2011	172.1	310.44	0	4'734	Swiss Federal Statistical Office (2012c)
Constructions ongoing	Average number of buildings under construction in 2010 and 2011	137.1	307.8	0	4'834	Swiss Federal Statistical Office (2012c)

Note: All variables used in the upcoming analyses are described. For metric and binary variables arithmetic mean (Mean), standard deviation (SD), minimum (Min) and maximum (Max) are shown. Nominal variables with multiple characteristics are merely described, but summary statistics are not presented.

As mentioned before, every single variable describes different aspects of a municipality. In particular, the combination of these variables allows a precise characterisation of municipalities.

Population and agglomeration

A weak indicator for the municipalities' population and agglomeration size is already given in the 'Municipality' variable. Two further variables are used to describe their size and agglomeration.[9]

Table 4.5: Agglomeration size index

Index	Agglomeration size	Sample frequency
7	> 500'000	57
6	200'000 – 499'999	68
5	100'000 – 199'999	38
4	50'000 – 99'999	57
3	< 50'000	48
2	Isolated town	5
1	Rural municipality	51

'Population' is the number of inhabitants in a municipality. 'Agglomeration' is an index for the agglomeration size, that is, how many inhabitants an agglomeration contains, as described in table 4.5. Agglomeration size is taken into consideration especially for infrastructure and joint service supply over different municipalities.

Tax and rent

Taxes and rents are important spendings for households. The tax burden 'Tax' is a weighted mean of spendings as a percentage of income for communal and

were implemented by using standard errors, which are corrected for cantonal clusters. Another solution would be to exclude all municipalities from small cantons. This approach is not applied because the results should hold for all 324 Swiss municipalities examined and all cantons.

[9] An agglomeration is defined as a cluster of geographically connected municipalities with at least 20'000 inhabitants. Each agglomeration's core area is defined as one or multiple municipalities that have at least 85 workplaces per 100 inhabitants.

cantonal income tax, as in equation (4.3). To calculate the 'Tax' variable, the tax burden tb as percentage of income for three types of persons p, namely a single, a married and a married person with two children are used. For every municipality j and income class i with relative frequency f, the arithmetic mean of these three percentages is calculated. Based on the national income distribution with 21 classes, see Swiss Federal Statistical Office (2010), the tax burden for an average Swiss income in municipality j is determined.

$$Tax_j = \sum_{i=1}^{21} f_i \left(\frac{1}{3} \sum_{p=1}^{3} tb_{p,i,j} \right) \tag{4.3}$$

Finally, the resulting average tax burden is indexed with a sample mean equal to 100 points by dividing all communal burdens by the average tax burden of the sample. According to this calculation, an average-income household in the most expensive municipality pays with 157.1 index points, nearly four times more than in the cheapest one, with 39.64. The smallest tax burden in this indicator is in Zug, whereas the largest one is in Val-de-Travers.

The variable 'Rent' is scaled as an index with sample mean equal to 100 points. The variable describes the average rent for a 4.5-room apartment in a municipality. It is estimated with a hedonic approach by comparis.ch (2012) and based on apartments offered on the internet. If fewer than 50 offers in a municipality were found, the entire district is used as an approximation. Because all municipalities contain more than 5′000 inhabitants, the data have to be approximated for only one municipality.

In Switzerland, renters invoice costs for water supply and sewer water as additional costs to the rent. The municipality-specific cost for household type 2 is deducted to avoid endogeneity issues. The highest index value is 195.07 in St. Moritz, followed closely by Geneva, with 194.01. The rents are nearly four times higher than in the cheapest municipality, with 57.25, which is Moutier.

Parliaments and finance commissions

The next category contains three variables on institutions in municipalities. The variable 'Parliament' indicates whether a municipality has a parliament

(1) or town meeting (0). It serves as an indicator for direct democracy on a communal level. In the sample, 43.2% of the municipalities have a parliament. Because the sample contains only the largest Swiss municipalities, this percentage is much lower throughout all Swiss municipalities.

The 'Finance commission index' is an indicator for the competences of institutions for financial control in municipalities, which is dependent on cantons. It was first developed by Eichenberger and Schelker (2007) and updated by Rühli (2012). Based on cantonal law, different elements of financial control are mandatory, recommended or not requested. The index evaluates the potential strength and competency within every canton.

Additionally, Rühli (2012) distinguished between institutions based on cantonal law as being mandatory or optional. This distinction is captured in the 'Finance commission dummies'. These are 'Accounts audit', 'Business audit', 'External audit' and 'Finance commission'. The dummies take a value of 1 if an institution is mandatory and 0 otherwise.

Constructions

To measure the construction activity in municipalities, 'Constructions finished', 'Constructions ongoing' and 'Building applications' are observed. These are aggregates for 2010 and 2011. 'Constructions ongoing' is measured every quarter and averaged over all eight quarters. In the subsequent analysis, the construction variables are used per capita, and are therefore divided by the population size of municipalities.

The minimum value of all construction variables is 0. In a municipality with at least 5′000 inhabitants, this is very unlikely to be true. The problematic 11 observations are later excluded from the estimations.

4.3.2 Absence of economies of scale

In this subsection, the question of whether economies of scale are detectable in price levels for government services is pursued. It is found that economies of scale generally do not become visible for households through lower prices. Recall that all municipalities in the sample have 5′000 or more inhabitants, so this result is only valid for large municipalities. The optimal size of municipalities is especially relevant for amalgamations of municipalities. For further research, investigating administered service prices in smaller municipalities, which are more likely to merge than larger municipalities, could contribute important facts to this discussion.

The upcoming estimations are for model specification (4.4). The influence of scale effects on administered prices is mainly estimated by relating administered price levels to the population and agglomeration size of a municipality. At the end of the subsection, additional modified functional forms will be estimated.

Administered prices levels 'AP', as dependent variables, are measured by the indexes presented in section 4.2. All price variables used are indexes with sample mean equal to 100 points. The main explanatory variables are population 'Pop' and agglomeration size 'Agg'. Agglomeration size is measured by an index with grouped observations, as seen in table 4.5. Population size is measured by the number of inhabitants. Population size and administered prices are specified with a logarithm because the specification is linear. By using a logarithm, residuals are more likely to be distributed normally, especially when using prices as the dependent variable. Agglomeration size is by its construction already a kind of linearised variable, due to the class intervals, and no logarithm is used.

$$log(AP_j) = \beta_0 + \beta_1 log(Pop_j) + \beta_2 Agg_j + \beta_k M_j + u_j \qquad (4.4)$$

Finally, the specification is completed by M, a set of dummy variables describing municipality j. In this basic specification, the seven dummies for the economic and demographic structure, as well as the language dummies, are used. The dummies for the economic and demographic structure characterise the municipality in a basic way. Language dummies are often used in studies in Switzerland to control for cultural influence. One might argue that in the context of administered prices for basic services, topography or cantons are more relevant than the cultural influences. At the end of this subsection, estimations using different model specifications are discussed.

The estimation of model specification (4.4) can be seen in table 4.6. The headline indicates the dependent variable. In estimations (1) to (4), the API with and without electricity (API_{-e}) are used as dependent variables. Once, each is used for an estimation with the complete sample containing all 324 observations, and then once on a reduced sample with no observation containing prices at zero. This is done to avoid merely looking at one sample, with or without the particular decision to finance services alternatively.

Electricity (EL), waste management (WM), sewer water (SW) and water supply (WS) prices are used as dependent variables in estimations (5) to (8). Here, data only contains municipalities with service prices that are not equal to zero. Remember that 39 municipalities have a waste management and 4 a water supply price equal to zero. Therefore, in estimations (6) and (8), fewer than 324 observations are used. All estimations are done by OLS.

In table 4.6, the estimated coefficients for the exogenous variables and their heteroscedasticity consistent standard errors are shown. The heteroscedasticity consistent standard errors are estimated as hc3, according to Long and Ervin (2000), using the R-package `tonymisc`.[10] The F-Statistic verifies whether population and agglomeration size collectively show an impact on administered price levels, tested by the joint hypothesis $H_0 : \beta_1 = \beta_2 = 0$. The normality of the residual distribution is monitored with the Jarque-Bera test in order to verify if the p-values of the coefficients are valid.

In the following, the results shown in table 4.6 are interpreted. First, the effects of economies of scales on the general administered price level are discussed. In estimations (1) to (4), only the coefficient for 'Agglomeration' in the estimation on the API_{-e} with the reduced sample size is significantly different from zero at a 5% level. With this specification and the underlying indexes, economies of scales cannot be detected in prices. Also, the joint hypothesis tests do not indicate any common influence of 'Agglomeration' and 'Population'. No F-Statistic is significantly different from zero. In set M, the seven municipality dummies are rarely significantly different from zero. 'Language' indicates that in the French and Italian-speaking areas, prices are relatively low compared to the German-speaking area.

[10]The hc3 standard errors correct, as mentioned, for heteroscedasticity, but also for small sample sizes. Therefore, the standard errors are estimated conservatively. In some of the following estimations, cluster robust standard errors are introduced. The basic estimations are made with hc3 and not cluster robust standard errors because it is ex ante not unambiguously clear which variable should be used to define the clusters.

Table 4.6: Absence of economies of scale

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	4.714***	4.711***	4.551***	4.511***	4.728***	5.297***	4.232***	3.699***
	(0.148)	(0.249)	(0.137)	(0.216)	(0.152)	(0.188)	(0.370)	(0.366)
log(Population)	−0.005	−0.009	0.010	0.009	−0.001	−0.062**	0.042	0.067
	(0.015)	(0.026)	(0.014)	(0.023)	(0.016)	(0.020)	(0.040)	(0.038)
Agglomeration	−0.009	0.014	−0.006	0.020*	−0.037***	0.023*	−0.011	0.050**
	(0.006)	(0.011)	(0.006)	(0.010)	(0.005)	(0.010)	(0.020)	(0.018)
Suburban	−0.033	−0.099*	−0.013	−0.077	0.045*	−0.096*	−0.031	−0.072
	(0.029)	(0.049)	(0.028)	(0.045)	(0.021)	(0.043)	(0.081)	(0.081)
High-income	0.029	0.012	0.066	0.053	0.044	−0.145*	0.188	0.159
	(0.041)	(0.070)	(0.041)	(0.070)	(0.034)	(0.058)	(0.110)	(0.109)
Peri-urban	−0.057	−0.125	−0.041	−0.101	0.014	−0.229**	−0.100	−0.012
	(0.040)	(0.076)	(0.039)	(0.064)	(0.034)	(0.082)	(0.131)	(0.107)
Tourist	−0.034	−0.067	−0.020	−0.027	−0.018	−0.200	0.165	−0.070
	(0.063)	(0.124)	(0.060)	(0.085)	(0.040)	(0.109)	(0.162)	(0.175)
Industrial	0.004	0.036	0.023	0.060	−0.036	−0.006	0.128	0.101
	(0.034)	(0.059)	(0.033)	(0.057)	(0.025)	(0.058)	(0.106)	(0.090)
Agronomic	0.000	−0.042	0.011	−0.033	0.029	−0.133	0.176	−0.142
	(0.077)	(0.156)	(0.069)	(0.143)	(0.033)	(0.088)	(0.244)	(0.176)
French	−0.071***	−0.213***	0.009	−0.066	0.072***	−0.174*	−0.161**	0.164**
	(0.021)	(0.036)	(0.029)	(0.050)	(0.016)	(0.072)	(0.060)	(0.051)
Italian	−0.159**	−0.440***	−0.107**	−0.338***	0.093**	−0.250**	−0.767***	−0.029
	(0.054)	(0.098)	(0.035)	(0.065)	(0.033)	(0.095)	(0.122)	(0.085)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.090	0.195	0.036	0.106	0.258	0.139	0.127	0.115
Jarque-Bera	0.805	14.407***	1.798	3.027	7.606*	32.956***	13.710**	33.840***
F-Statistic	1.325	0.779	0.456	2.780	28.736***	3.940*	0.459	8.781***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table. The F-test is for the joint hypothesis that agglomeration and population size mutually do not show any significant impact on the dependent variable.

Compared to overall administered price levels in estimations (1) to (4), estimations on single service prices in (5) to (8) yield, to some extent, different, but still inconsistent results. Four out of eight estimated coefficients for 'Agglomeration' and 'Population' are significantly different from zero. Two are positive, two are negative. Agglomeration size has a negative effect on electricity prices. The population size of a municipality has no impact on the prices of the locally supplied services of water supply or sewer water. However, over all four services, no clear tendency in how economies of scale interact with administered service prices can be identified. Additionally, the F-Statistics for the joint hypothesis $H_0 : \beta_1 = \beta_2 = 0$ indicates that for all services apart from sewer water, agglomeration and population size have a joint influence. But, as discussed earlier, the estimated coefficients do not yield a consistent result over all services. The variables of M show an influence similar to those in estimations (1) to (4). Municipality dummies have overall only a few significant estimated coefficients, whereas the language dummies indicate differences between linguistic regions.

The estimation performance is described by measuring its explanatory power and verifying the residual distribution. Remember that heteroscedasticity consistent standard errors are used. Generally, the adjusted R-squared is between 9.0% and 25.8%. In one single estimation, it is 3.6%, which indicates extremely little explanatory power. This disqualifies this model specification to some extent. The Jarque-Bera tests indicate that five of the eight estimations have problematic residual distributions. All estimations on single prices have problematic distributions, whereas only one of the estimations on the API or API_{-e} has non-normally distributed residuals. The significances of estimated coefficients on single service prices are therefore not valid.

How should these results be judged? Or, more precisely, are prices affected by economies of scale? Based on these estimations, the answer is 'no'.

That economies of scale are overall not visible, or at least not in 'valid' estimations, does not mean that they are nonexistent. Maybe service production costs are affected, but producers, administrations or governments do not give these benefits to the households over prices. Maybe scale effects are effectively not present, because a large agglomeration or population size also brings disadvantages, as more complex networks or supply chains. Or, the effects might become visible if all smaller municipalities with less then 5′000 inhabitants were included. Then, estimations on water supply and sewer water service prices in particular might yield different results. However, the findings confirm the results of Pommerehne (1983), who did not find economies of scale in waste management service prices either. Other explanations for missing economies of scale might be econometric problems. The explanatory power of the basic model is weak, as seen in the very low adjusted R-squared. The model might be specified badly and suffer from omitted variable bias. To test this last issue, some further specifications are estimated. The section dealing with economies of scales will conclude with a discussion of three alternate specifications to see whether scale effects might become visible.

To change the specification, population and agglomeration size are specified differently, as shown in table A.13 in the appendix. Population size is not used as logarithm, and agglomeration size is complemented by the agglomeration size squared. The change in population does not break the non-linear distribution, which allows us to see the full impact of population size on administered prices. The added square of agglomeration size allows the estimation to account for difficulties that can emerge in large agglomerations, such as complex supply chains or networks. The modifications do not change the results of the basic estimations. The change is that only two F-Statistics remain significant, so even 'less' economies of scale can be observed with this specification change. Also, similar specifications using, for example, the square of 'Population', did not yield different results. Using standard errors that are robust for cantonal clusters also does not change the results.[11]

The second modification presented includes topography instead of language dummies. Administered prices could also be affected by the underlying topography of a municipality. The topography is split very roughly, as shown in table A.14. No changes to the results are obtained. The estimated coefficients for the economies of scales variables do not become significantly different from zero. The R-squared are even lower than in the basic estimations. Addi-

[11] Cluster robust standard errors are used in the following subsections to control for cantonal influences. Note that other clusters could also be considered, for example, for municipalities with similar costs of living (approximated through tax burden or rents), topographical characteristics or political similarity in terms of the prevailing ideology of the governments. This is the main reason why hc3 standard errors, and not specific cluster robust standard errors, are used in the basic estimations.

tionally, no significant influence of topography on administered prices can be detected.

Administered prices are, per definition, influenced by governments or administrations. It is very likely, as seen and discussed in section 4.2, that prices are distributed differently across cantons. Therefore, in the estimations, one should include cantons. But controlling for each and every canton is very difficult. The main problem is that several cantons have only one municipality in the sample, which causes problems in the estimation of coefficients because inverting the design matrix is not always possible. However, Switzerland can be divided into large regions, as done in the last set of estimations, shown in table A.15. These regions are all geographically connected and cover different cantons and parts of cantons. Using regions does not change the results obtained before. Nonetheless, the adjusted R-squared rise significantly in all estimations, confirming that regional or cantonal effects play an important role in administered price levels.

4.3.3 Relation to tax rates and rents

Income tax rates and rents are key variables for households and constitute a considerable share of their spendings. In this subsection, the relation between administered price levels, tax rates and rents in municipalities is analysed. Tax rates and administered price levels show in most estimations a significantly positive relation - therefore, municipalities with high tax rates usually show high API values. Rents and administered prices appear to be independent.

Tax rates and rents are important variables for households, and they also affect the choice of residence. If income is high, tax burden becomes more relevant than rent. If income is low, tax rates do not matter that much, but the rent becomes increasingly important. Both variables are important not only for households, but also for municipalities. If tax rates are low and the mechanism of capitalisation works, rents are high because households are attracted to and willing to pay a lot to live in the municipality. If tax rates are high, households are deterred and are not willing to pay much to live there. As a result, the rents are typically low in such municipalities.

Since this is mainly a descriptive approach to relating tax burden and rents to administered prices, again a linear model specification is chosen. 'Tax' and 'Rent' are included with the corresponding indexes, described in subsection 4.3.1. Because a household pays different cantonal and communal income tax in municipalities, both are included in the 'Tax' variable. To include only communal income tax burden in the tax variable would correspond to only considering services provided by municipalities. Because electricity and waste management services are provided over multiple municipalities or even cantons, cantonal income tax is also included. For the variables 'AP', 'Tax' and 'Rent', the logarithm is taken to maintain the linearity of the model specification in the variables as well. The model specification in equation (4.5) is again completed by the set M, describing municipality type and official language.

$$log(AP_j) = \beta_0 + \beta_1 log(Tax_j) + \beta_2 log(Rent_j) + \beta_k M_j + u_j \qquad (4.5)$$

The estimations are OLS. In the table 4.7 are estimated coefficients with heteroscedasticity consistent standard errors reported (below, in parenthesis). In the estimations (1) to (4), both the API as well the API$_{-e}$ are estimated each on the complete sample of 324 municipalities and on a restricted sample of 281. The restricted sample excludes all municipalities with any service price equal to zero. In estimations (5) to (8), every service is used once as dependent variable. For each estimation, municipalities with service price equal to zero (of the dependent variable) are excluded. The residual distribution is tested on normality through Jarque-Bera tests.

The estimation results are summarised in table 4.7. In seven out of eight estimations, tax burden shows a significantly positive impact on administered prices (at 5%). Consider that both variables are used in logarithmic form. Therefore, the estimated coefficients between 0.127 and 0.542 indicate quite a strong relationship. In estimations (1) to (4) with API and API$_{-e}$, general administered price levels increase per percent of tax burden by approximately 0.2% to 0.3%. In the estimations on single prices, especially in water supply and sewer water, prices increase for every percent of tax burden by about 0.5%. Again, both are strong relationships. The fact that tax burden and administered prices have a significant positive relation to three different service prices and differently aggregated indexes with varying databases is a notable result. The relation to rent can not be identified based on these estimations. One co-

Table 4.7: The relation to tax rates and rents

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.517***	5.493***	6.052***	4.266***	4.620***	5.229***	1.000	0.317
	(0.418)	(0.765)	(0.430)	(0.742)	(0.361)	(0.823)	(1.162)	(1.217)
log(Tax)	0.211***	0.277***	0.202***	0.296***	0.127**	−0.069	0.542***	0.424**
	(0.052)	(0.082)	(0.051)	(0.076)	(0.042)	(0.058)	(0.119)	(0.129)
log(Rent)	−0.069	−0.046	0.044	0.208	−0.139**	−0.033	0.245	0.504**
	(0.052)	(0.111)	(0.058)	(0.108)	(0.048)	(0.134)	(0.160)	(0.173)
Suburban	−0.017	−0.033	−0.021	−0.041	0.003	−0.011	−0.062	−0.041
	(0.019)	(0.033)	(0.019)	(0.031)	(0.017)	(0.031)	(0.054)	(0.055)
High-income	0.097**	0.156*	0.077*	0.104	0.036	−0.033	0.170	0.149
	(0.033)	(0.064)	(0.033)	(0.062)	(0.032)	(0.056)	(0.088)	(0.092)
Peri-urban	−0.052	−0.079	−0.059*	−0.082	−0.028	−0.122	−0.162	−0.031
	(0.030)	(0.060)	(0.030)	(0.048)	(0.028)	(0.071)	(0.106)	(0.077)
Tourist	0.001	−0.064	−0.023	−0.082	0.064	−0.171	0.131	−0.265
	(0.049)	(0.103)	(0.050)	(0.074)	(0.040)	(0.111)	(0.156)	(0.173)
Industrial	0.019	0.001	0.021	0.003	0.042*	0.004	0.099	−0.085
	(0.027)	(0.049)	(0.027)	(0.050)	(0.020)	(0.054)	(0.093)	(0.077)
Agronomic	−0.002	−0.098	−0.003	−0.104	0.092**	−0.117	0.120	−0.334*
	(0.072)	(0.149)	(0.066)	(0.140)	(0.032)	(0.090)	(0.240)	(0.152)
French	−0.078***	−0.232***	−0.023	−0.120*	0.084***	−0.169*	−0.230***	0.066
	(0.022)	(0.042)	(0.028)	(0.051)	(0.017)	(0.072)	(0.067)	(0.066)
Italian	−0.115*	−0.383***	−0.068	−0.279***	0.122***	−0.253**	−0.664***	0.062
	(0.052)	(0.093)	(0.035)	(0.062)	(0.037)	(0.098)	(0.122)	(0.082)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.223	0.254	0.125	0.148	0.253	0.118	0.180	0.115
Jarque-Bera	1.973	27.792***	0.184	0.025	10.659**	24.050***	30.316***	33.787***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

efficient is significantly positive, one negative and the others not significantly different from zero. In the given model specification and with underlying data, no relation can be detected.

Adding 'Tax' and 'Rent' also alters overall estimation performance. The adjusted R-squared is between 11.5% and 25.4%. Especially in the first four estimations with general administered price levels, taxes and rents improve the explanatory power by quite a bit when compared to the specification with economies of scale variables. Nevertheless, overall prediction quality is still low, and other specifications and variables are needed to obtain good explanatory power. The Jarque-Bera tests indicate, as in the last subsection, issues in the residual distribution. In the estimations with complete indexes, only one residual distribution is not normal. In the single service price estimations (5) to (8), distributions do not appear to be normal at all. Again, estimations on single service prices have residual distribution problems, so estimated coefficients should be interpreted carefully. On the other hand, the results in the first four estimations with the API and API_{-e} are quite clear and seem so far to be unproblematic, apart from the low adjusted R-squared. As an intermediate result, taxes and administered prices are positively related. A municipality with high income tax burden typically shows high administered prices. Before discussing this result more in depth, some estimation variants are presented.

As a first modification in the model specification, population and agglomeration are added to the model. The estimated results are in table A.16. Even though the conclusion of the last subsection does not confirm the presence of economies of scale, along with tax and rent, a joint effect might occur. However, the results do not change at all. Tax remains just as significant as without economies of scale variables. And neither population nor agglomeration becomes systematically significant. The only recognisable change is that explanatory power, measured by the adjusted R-squared, and therefore corrected for relatively more variables, rises slightly.

Tax burden is influenced by cantons because it contains communal and cantonal income tax. Therefore, controlling for cantons is necessary. The problem is again that some cantons only have one observation and many cantons only a few. Given these circumstances, adding cantonal dummies poses problems for estimating the coefficients because the design matrix cannot be inverted. Alternatively, the municipalities of the small cantons could be excluded from the estimation. This approach is not applied, because the results should be valid for all Swiss municipalities with more than 5′000 inhabitants. Therefore, instead of cantonal dummies, regional dummies are added to replace language dummies, as shown in table A.17 in the appendix. This change results in non-significant estimated coefficients for 'Tax', with the API_{-e} as endogenous variable. They are still positive, but no longer significantly different from zero.

Cantonal influence can be considered by using standard errors for cluster samples. Estimations using the Huber-White method are made with the R-package `rms` and reported table A.18. Correcting standard errors for cantonal clusters confirms that other (omitted) cantonal variables could influence administered prices. The standard errors become larger, and only two out of eight coefficients remain significantly different from zero. Most other p-values are between 5% and 7%.

Both previous estimation variants weakened the initial finding that income tax burden and administered prices show a significantly positive relation in general. Using standard errors for cantonal clusters in particular indicates that cantonal influences are important for this relationship. This is due to the nature of basic services, especially for electricity and waste management, which are not produced individually for each municipality, such that prices may be identical in cantons or regions. In addition, the tax variable contains cantonal income tax. Nevertheless, concluding that taxes and administered prices across municipalities (at least across cantons) have a (weak) positive relation does not seem to be entirely wrong. In all estimations with different dependent variables or standard errors, all estimated coefficients were positive. If they are not significant, the p-values are close to 5%. Up to now, the discussion has been mainly descriptive. What implications do these results have?

A slightly more extended interpretation of these results is offered below. This is not an hypothesis test, but it should illustrate an aspect of the estimation results. The positive relation between tax burden and administered prices could indicate that there are some municipalities that are more financially sound than others. Even though municipalities may not receive all of the revenue from the services (because user charges are only a part of the administered price), they still have a certain price-setting power. They often receive at least part of the revenue through user charges. If a municipality has enough means, revenues or other assets, there is no need to have high tax rates or administered prices (through contained high user charges) for basic services. However, in the opposite case, municipalities that are not financially sound have high tax rates and also ask their households for the 'full' price for its services, maybe containing elements like relatively high reserves for depreciations, for example.

This idea can be developed. What would be the conclusion if the estimated coefficients were negative instead of positive? This would signify that municipalities have high tax rates and low service prices or vice versa. In this hypothetical scenario, it is very likely that municipalities would substitute between revenue, therefore either compensating for low tax revenue with user charges and administered prices, or for low administered prices with high tax rates. This could violate the benefits principle. Finally, there are no hints of such behaviour. As mentioned, the results point in the opposite direction, that municipalities are either financially sound or not. Again, how much municipalities can influence prices and revenue from these services is an open question. The positive relation between tax rates and administered price levels is described here. Further research might provide better theoretical insights.

4.3.4 Institutional influence on price levels

After verifying the relation of administered prices to economies of scale, rents and tax burden, in the upcoming subsection, the question of how administered prices could be controlled or, more precisely, be influenced by institutions is pursued. Two different types of institutions on the municipal level are considered in this approach, namely direct democracy and financial control. Based on the underlying model specifications, estimations and data, municipalities in cantons with strong finance control tend to have lower prices for the four basic services. Direct democracy, measured by the presence of town meetings (versus communal parliaments), does not affect prices in municipalities significantly. The results have to be interpreted very carefully because finance commission variables are constructed on the cantonal level. As before, other (omitted) cantonal influences might affect the analysis.

In Swiss municipalities, democratic decision making might be direct, through town meetings, or representative, through a parliament. The findings of Feld et al. (2003) and Matsusaka (2008) indicate that a direct democracy, compared to a representative democracy, may shift revenue generation from taxes to user charges. They also find that direct democracy causes smaller governments in terms of revenue and spendings. Therefore, revenue generated from user charges (and subsequently administered prices) is differently influenced by a direct democracy than other revenue. The main explanation for this observation, according to the authors, is that government revenue that can be justified by a service is accepted by the people and therefore accepted in (direct) votes. Politicians in representative systems are less focused on how revenue is generated, which is quite plausible. Their studies are on a cantonal level, so they are only conditionally comparable to this study analysing municipalities. Pommerehne (1983), on the other hand, stated that municipalities with direct democracy (town meetings) showed lower prices for waste management services. He pointed out that control mechanics in direct democracies are much stronger, which might cause this difference.

The democratic system is included in the model specification in equation (4.6) by the dummy variable 'Parliament', indicating whether a municipality has a parliament (1) or town meetings (0). The second variable of interest is the strength of finance commissions, measured by the index 'FinCom'. The finance commission index, originally suggested by Eichenberger and Schelker (2007) and updated by Rühli (2012), describes how strong the mandatory elements financial control of a municipality are. This measure is based on cantonal law. The variable does not capture how efficiently these mandatory elements are actually implemented, but indicates at least its minimal standards, which are defined by cantonal law as a lower threshold. Note that the index takes identical values for every municipality in a canton.

The key institutions in communal financial control are 'Accounts audit', 'Business audit', 'External audit' and 'Finance commission'. Based on cantonal law, these are either optional, recommended or mandatory. The effects of these institutions is investigated in the second part of this subsection. As mentioned before, the results have to be interpreted very carefully because other effects at the cantonal level are very likely to be omitted. As seen in section 4.2, price setting varies within and throughout cantons. Suppliers are often present over multiple municipalities, and so similar or identically set prices might end up showing in the estimated coefficients for cantonal variables.

In the basic model specification, in equation (4.6), 'Tax' is added because of its earlier significance. The specification is again completed by set M, containing dummies for municipality type and language.

$$log(AP_j) = \beta_0 + \beta_1 Parl_j + \beta_2 FinCom_j + \beta_3 log(Tax_j) + \beta_k M_j + u_j \quad (4.6)$$

The results are reported in table 4.8. All estimations are again OLS with heteroscedasticity consistent standard errors. Estimations (1) to (4) are with the API and API_{-e}. Estimations (1) and (2) are on the complete sample, containing all 324 observations. Estimations (3) and (4) are on the restricted sample, with 281 municipalities, excluding all municipalities with any administered service price equal to zero. Estimations on single prices are in estimations (5) to (8). Again, all observations with corresponding prices equal to zero are excluded. The Jarque-Bera tests are carried out to observe residual distributions.

The estimation results are shown in table 4.8. Again, as in the previous section, one variable shows influence, whereas the other does not seem to have any relevance for prices. A p-value below 5% is required for a variable to be considered as significantly different from zero. Direct democracy on a communal level, measured by the presence of town meetings and parliaments, does not have significant impact on price levels. The coefficients are estimated to be positive. Therefore municipalities with parliaments do have slightly higher price levels, but not significantly different from municipalities with town meetings. The only significant estimated coefficient is for water supply, the most locally organised service. This is also confirmed in further estimations, which are discussed below. Note that the Jarque-Bera tests indicate residual distribution problems, and p-values might not be valid. The coefficients for the strength, or more precisely, potential strength, of finance commissions is consistently estimated to be negative. In half of the estimations, coefficients are

Table 4.8: Institutional control of administered prices

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.214***	5.342***	6.499***	5.735***	3.857***	5.239***	2.714***	3.833***
	(0.214)	(0.346)	(0.189)	(0.281)	(0.155)	(0.172)	(0.412)	(0.482)
Parliament	0.012	0.021	0.019	0.032	0.001	−0.009	0.013	0.135*
	(0.019)	(0.037)	(0.018)	(0.031)	(0.016)	(0.031)	(0.058)	(0.058)
FinCom	−0.024**	−0.024	−0.024**	−0.024	−0.026***	−0.034**	−0.012	−0.015
	(0.008)	(0.014)	(0.008)	(0.013)	(0.007)	(0.012)	(0.023)	(0.023)
log(Tax)	0.216***	0.270***	0.153***	0.183**	0.166***	−0.092*	0.410***	0.140
	(0.045)	(0.073)	(0.040)	(0.059)	(0.032)	(0.037)	(0.086)	(0.102)
Suburban	−0.014	−0.026	−0.006	−0.011	−0.002	−0.006	−0.033	0.036
	(0.019)	(0.033)	(0.020)	(0.032)	(0.016)	(0.032)	(0.054)	(0.058)
High-income	0.083**	0.152**	0.100**	0.178**	−0.002	−0.041	0.249**	0.340***
	(0.030)	(0.053)	(0.030)	(0.057)	(0.027)	(0.046)	(0.078)	(0.085)
Peri-urban	−0.042	−0.063	−0.036	−0.040	−0.028	−0.115	−0.136	0.076
	(0.031)	(0.059)	(0.031)	(0.051)	(0.028)	(0.076)	(0.114)	(0.085)
Tourist	−0.007	−0.068	−0.019	−0.061	0.047	−0.184	0.154	−0.195
	(0.050)	(0.110)	(0.046)	(0.070)	(0.032)	(0.107)	(0.147)	(0.169)
Industrial	0.028	0.013	0.029	0.011	0.048*	0.006	0.100	−0.042
	(0.030)	(0.053)	(0.031)	(0.053)	(0.021)	(0.058)	(0.101)	(0.077)
Agronomic	−0.007	−0.099	−0.006	−0.105	0.084*	−0.136	0.111	−0.298
	(0.072)	(0.149)	(0.065)	(0.138)	(0.037)	(0.087)	(0.237)	(0.170)
French	−0.094***	−0.250***	−0.033	−0.136**	0.064***	−0.164*	−0.196**	0.066
	(0.022)	(0.042)	(0.030)	(0.050)	(0.017)	(0.072)	(0.066)	(0.066)
Italian	−0.087	−0.364***	−0.056	−0.292***	0.166***	−0.201*	−0.678***	−0.062
	(0.054)	(0.100)	(0.036)	(0.064)	(0.040)	(0.100)	(0.124)	(0.097)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.240	0.260	0.157	0.145	0.256	0.134	0.170	0.093
Jarque-Bera	0.449	9.455**	0.938	1.816	4.036	30.0164***	21.406***	38.311***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

significant at the 5% level. Remember that the FinCom-index takes values between 0 and 3; see table 4.4. A high index value indicates a potentially strong financial control. Per increased index point, in the estimations (1) to (4) the administered price level is 2.4% lower. For water supply and sewer water services, prices are lower by 1.2% and 1.5%, respectively, if the index is increased by 1. For waste management and electricity services, the impacts are 3.4% and 2.6% stronger, respectively, when the index is increased by 1.

Without any further extensive discussion or estimations, municipalities with potentially strong finance commissions tend to have lower service price levels. However, the finance commission index (FinCom) is based on cantonal law. Other cantonal effects may have been omitted. The intermediate result should not be overrated, and it must be interpreted carefully. Adding institutional variables does not change the overall estimation performance much. The adjusted-R squared remains approximately at the same level as in the estimations with tax burden and rent. Instead of five, only four estimations have problematic residual distributions, as indicated by the Jarque-Bera test. Again, three estimations with the API and API_{-e} show normally distributed residuals.

To obtain better insight into the relation between administered price levels and individual institutions, the specification is slightly altered. Single institutions replace the 'FinCom' index to see whether one institution in particular could influence the results. In a second step, regions are added to control for local effects. In a third step, it will be shown that without control for regions or languages (and only topography), the 'FinCom' index is much more relevant for administered prices. Finally, the model is estimated with cluster robust standard errors.

As previously discussed, the following four institutions are very important elements in the financial control: 'Accounts audit', 'Business audit', 'External audit' and 'Finance commission'. The 'FinCom' index is replaced by four dummies, which take the value 1 if an institution is mandatory in the corresponding canton, and 0 otherwise. The results, as seen in table A.19 in the appendix, show that two groups can be formed. External and business audit coefficients are, with one exception, always negative and sometimes significant. Accounts audit and finance commissions have negative and positive estimated coefficients, respectively, and they are rarely significantly different from zero. Replacing the 'FinCom' index with single institution dummies does not yield robust results. Remember also that these dummies are based on cantonal law, and therefore interpretations should be made cautiously.

The 'FinCom' index is based on cantonal law. Controlling for cantons by adding canton dummies would make the index redundant. Therefore, regions replace language dummies, as shown in table A.20 in the appendix. The influence of parliaments remains weak; only in water supply is a significant negative coefficient estimated. For the 'FinCom' index, all estimated coefficients become very small, some even positive and none is still significantly different from zero. The extent to which this is caused by the grouping of cantons through regions, or if truly no effects exist, is an open question. However, regional grouping takes away a lot of the explanatory power of the 'FinCom' index. If language or region dummies are replaced by topography, as in the estimations in table A.21, the estimated coefficients for the index are all negative, and six of eight significantly different from zero.

There are strong indications that measured institutional influence on administered prices might be driven by other cantonal variables. Estimating standard errors for cluster samples confirms this impression, as seen in table A.22. No 'FinCom' coefficient remains significant. Interestingly, four out of eight coefficients for tax remain significantly positive. On the other hand, the 'FinCom' index is the only index measuring the strength of financial control in Switzerland. Other measures would first have to be constructed for municipalities to verify these results. Direct democracy, measured by the presence of town meetings and parliaments, has almost never shown any significant relation to administered prices, despite being constantly positive.

The section is closed with a remark about what is not implemented in this subsection. One contribution of Eichenberger and Schelker (2007) is the framework of institutional competition between finance commissions or audit and the government. In their index for institutional competition, the cantonal percentage of town meetings is multiplied by the strength of finance commissions as an indicator for institutional competition. With municipalities and not cantons as observations, an interaction term between the binary dummy (1: town meeting, 0: parliament) and the 'FinCom' index can be created.

Then, the relative effect of strong finance commissions in municipalities with town meetings could be estimated. As in this project, administered prices, and not institutional competition, are focused on, this is an open area for further research.

4.3.5 No sign of capitalisation in rents

Section 4.3 closes with a discussion of the influence of administered prices on municipalities via capitalisation. Fiscal variables, namely debts and the height of tax rates, influence municipalities' ground or house prices, as well as rents. A wide spectrum of literature exists on how fiscal decisions influence municipalities, mostly based on Oates (1969). In the Swiss context, Feld and Kirchgässner (1997) analysed the influence of tax rates on rents. Stadelmann (2009) did the same for house prices. The following analysis tests whether administered prices (now as explanatory variable) have an impact on rents. No significant influence is found.

In model specification (4.7), the dependent variable is 'Rent'. As before, the additional costs for water supply and sewer water services are excluded. As the main explanatory variable, the different administered price indexes are used, namely the administered price index (API), the API without electricity (API_{-e}), electricity (EL), waste management (WM), sewer water (SW) and water supply (WS).

As complementary explanatory variables, 'Tax', as well as the set of economic and demographic municipality characteristics M, are included. In M, population size and the seven municipality type dummies are included. Due to the dependence of rents on apartment quality, 'Constructions' are added, to include an indicator for building quality. This is the average number of buildings under construction during 2010 and 2011 per inhabitant of a municipality.

$$log(Rent_j) = \beta_0 + \beta_1 log(AP_j) + \beta_2 log(Tax_j) + \beta_k M_j + u_j \qquad (4.7)$$

The estimation results for specification (4.7) are summarised in table 4.9. In estimations (1) to (4), the API as well as the API_{-e} are used as explanatory variables. In estimations (2) and (4), 'Construction' is set aside. In estimations (5) to (8), price indexes of the single services are used, and construction activity is always included. As database a subsample containing 271 municipalities is used for all estimations. All municipalities with construction activity, water supply or waste management price equal to zero are excluded. The estimations are again OLS, and the residual distributions are observed by Jarque-Bera tests.

This is the moment to address a few words to the endogeneity of explanatory variables. Up to now, the administered prices have been the dependent variables. There are neither theoretical nor empirical hints that administered prices might systematically influence any of the other variables used so far. Therefore, this was never discussed. 'Rent', on the other hand, might influence 'Tax', 'Construction' or 'Population'. Surprisingly, in the capitalisation literature, it is predominantly assumed that 'Rent' does not influence 'Population', 'Construction' or 'Tax'. This assumption is also made for the following estimations, although it is not free of doubt.

The interpretation of the estimations for capitalisation of administered prices on rents is very straightforward, as can be verified in table 4.9. With the exception of electricity, no service capitalises negatively in rents. The coefficients for services in six estimations do not significantly differ from zero. Water supply capitalises positively in rents. Important for the results mentioned above is, that all other control variables behave as expected. Most importantly, in all estimations, tax burden capitalises significantly negative in rents (at the 5% level). This result is consistent with capitalisation literature. Construction activity's influence on rents is significantly positive. The higher the construction activity, the higher the building quality and subsequent rents. As already mentioned, other dependences have to be considered, such as incentives to construct buildings in municipalities with a low tax burden or in city centres. Through the independence assumption from above, this issue - which is clearly important - will not be further discussed. Finally, all coefficients for municipality dummies, as well as population size, are estimated to be significantly different from zero.

The overall estimation performance evaluated by adjusted R-squared and Jarque-Bera tests can be characterised as follows. The adjusted R-squared are above 50%, which is high compared to the results of the previous subsections. The

Table 4.9: Capitalisation of administered prices

	(1) Rent	(2) Rent	(3) Rent	(4) Rent	(5) Rent	(6) Rent	(7) Rent	(8) Rent
Constant	4.732***	4.987***	4.760***	4.953***	5.607***	4.908***	4.958***	4.871***
	(0.318)	(0.322)	(0.268)	(0.276)	(0.387)	(0.362)	(0.249)	(0.255)
log(Tax)	−0.333***	−0.356***	−0.336***	−0.361***	−0.300***	−0.320***	−0.328***	−0.332***
	(0.039)	(0.041)	(0.039)	(0.040)	(0.037)	(0.036)	(0.039)	(0.037)
log(Population)	0.095***	0.090***	0.092***	0.087***	0.090***	0.096***	0.094***	0.091***
	(0.017)	(0.018)	(0.016)	(0.017)	(0.015)	(0.016)	(0.016)	(0.017)
Suburban	0.150***	0.139***	0.147***	0.136***	0.141***	0.149***	0.148***	0.149***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
High-income	0.359***	0.352***	0.350***	0.342***	0.357***	0.366***	0.359***	0.350***
	(0.051)	(0.051)	(0.050)	(0.050)	(0.049)	(0.050)	(0.051)	(0.050)
Peri-urban	0.190***	0.174***	0.188***	0.173***	0.173***	0.188***	0.186***	0.183***
	(0.035)	(0.034)	(0.036)	(0.035)	(0.038)	(0.035)	(0.037)	(0.036)
Tourist	0.162***	0.162***	0.164***	0.165***	0.162***	0.164***	0.159***	0.166***
	(0.041)	(0.044)	(0.042)	(0.045)	(0.044)	(0.042)	(0.043)	(0.041)
Industrial	0.059*	0.054	0.057	0.052	0.059*	0.061*	0.059*	0.061*
	(0.029)	(0.031)	(0.030)	(0.031)	(0.030)	(0.029)	(0.030)	(0.030)
Agronomic	0.080**	0.076**	0.087***	0.084**	0.090***	0.082**	0.077**	0.094***
	(0.027)	(0.029)	(0.025)	(0.026)	(0.027)	(0.028)	(0.028)	(0.025)
Constructions	3.903***		3.800***		3.420***	3.817***	3.841***	3.846***
	(0.945)		(0.941)		(0.978)	(0.966)	(0.940)	(0.941)
log(API)	0.065	0.053						
	(0.062)	(0.063)						
log(API_{-e})			0.068	0.071				
			(0.041)	(0.043)				
log(EL)					−0.144*			
					(0.071)			
log(WM)						0.013		
						(0.057)		
log(SW)							0.014	
							(0.023)	
log(WS)								0.044*
								(0.022)
N	271	271	271	271	271	271	271	271
adj. R-squared	0.574	0.551	0.578	0.557	0.580	0.572	0.573	0.579
Jarque-Bera	13.952***	11.161**	17.644***	14.721***	19.753**	16.751***	15.581***	9.463**

Note: The dependent variable is the logarithm of 'Rent'. All price indexes, namely API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply) are used as explanatory variables. All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

characteristic variables for municipalities explain rents much better than administered prices. The main problems with this analysis are the residual distributions. All Jarque-Bera tests indicate that residuals are not normally distributed, so all p-values are not valid, and the results in general have to be interpreted carefully.

So far, no influence of administered prices on rents has been detected. Despite the fact that water supply prices capitalise positively - which cannot be explained - electricity prices capitalise significantly negative. This could be because it is by far the most expensive price in the index. The explanatory power of the estimations is sufficient, and not as low as before. Nevertheless, maybe with other specifications, significant coefficients could be detected. In a first step, different construction activity variables are used. Secondly, regions are added as before because maybe regional effects are again present.

In table A.23, 'Constructions ongoing' is replaced by 'Constructions finished' (CF) and 'Building applications' (BA) in 2010 and 2011. Again, both variables are per capita. By adding these variables, a larger time interval is considered for construction activity. All finished constructions could have been started before 2010. And applications are maybe still under construction in 2012. The application variable also captures the demand for the construction of buildings in a municipality. The key results do not change. Administered prices do not capitalise, whereas tax burden still does. 'Constructions finished' is in all but one estimation significantly positive. On the other hand, the building applications from 2010 and 2011 have positive estimated coefficients, but they are not significantly different from zero.

In the second modification, in table A.24, regions are added. Also in this modification, the most important results remain the same as in the genuine approach. Tax burden still capitalises, but administered prices do not. The change is that it is not the municipality type dummies that have significant coefficients, but the regions.

Overall, it can be summarised that administered prices for the underlying services do not capitalise significantly on rents. Intuitively, two explanations can be offered for this result. Firstly, compared to the amounts paid for taxes, the amounts for government services are low for most households. Secondly, the perception of several single and committed spendings might be weak compared to one as large and general as taxes. However, if households were perfectly rational, every Swiss franc spent should capitalise negatively. But this cannot be observed. Perhaps the intuition of Feld et al. (2003) can be used here. If a household sees what money is spent on, it 'accepts' it more than if it is just 'lost' tax money.

If more services were included in the index, maybe capitalisation could be detected. Nevertheless, the index includes the most expensive services in terms of household spendings on a communal level. Another important issue related to capitalisation is that administered prices are independent of income but dependent on the consumption of services. Therefore, households with high incomes are much more aware of the tax burden than administered price levels. They are mobile and can afford to pay high rents. Thus, their willingness to pay for a rent in a municipality with low tax burden end up influencing the rents. The administered prices analysed affect households maximally by a small, four-digit CHF amount per year. Income taxes for average incomes are usually higher. Therefore, households that are mobile and can afford high rents do not care very much about administered prices. In the end, high administered prices are not necessarily bad. It could also indicate that cost transparency is given in a municipality, and every household pays only for its consumption, but not via taxes for the consumption of other households.

Contrariwise, low-income households pay lower taxes, but still consume basic services and have to pay for them. The expenditures for basic services of low-income households with many members can be a serious financial burden. But low-income households, which are affected much more by administered prices, are less mobile. Because of the smaller budgets for rents and mobility, households with a low income are not able to influence the rents. Thus, contrary to tax rates, the mechanisms of capitalisation in rents should not work with administered prices, as is confirmed by the empirical results.

4.4 Summary and outlook

This section contains three parts. The main findings are summarized in 4.4.1. After the summary, two outlooks follow. Based on the findings in the empirical section, one possible role of administered prices in fiscal competition is discussed in 4.4.2. Finally, the idea of a cost-of-living index for Swiss municipalities is outlined in 4.4.3.

4.4.1 Summary

Administered prices for basic services are measured and compared among the 324 largest Swiss municipalities in 2012. An index to measure service prices is developed. The index measures the total price or cost of all services for a representative Swiss household. The index shows that the prices for basic services vary considerably across municipalities. That is to some extent surprising because services are of a similar quality across all municipalities, communal governments administer the prices and the benefits and cost recovery principles should be respected. To discuss the observed price differences, administered service prices are related to municipality characteristics. Municipalities with relatively low tax burden and strong finance commissions tend to show lower service prices. To what extent these results are dependent on omitted cantonal variables is an open issue for further research.

Index for administered prices of basic services in Swiss municipalities

In section 4.2, a consumption profile-based index for administered prices in municipalities is constructed. Due to tariff plans, prices for three different household consumption profiles are used to determine representative service prices. In the resulting API for the 324 largest Swiss municipalities, a majority of municipalities have API values between 80 and 120 points. Assuming that services are approximately of a similar quality across all municipalities, the extreme values in the index come as a surprise.

Whereas in the complete API, the spread is between 62 and 152 points, excluding electricity widens it to 38 to 180 points. Therefore, in the most expensive municipality, a similar basket of services costs about 4.5 times more than in the most favourable one. High administered prices are not necessarily bad, keeping in mind that cost recovery and benefits principle allow providers to charge the cost incurred. In a few municipalities, waste management or water supply services are financed fully or at least partially by other revenue. The price level differences between municipalities are discussed in section 4.3.

For this purpose, the administered price indexes are related to municipality characteristics.

Positive relation between tax burden and administered prices

The most robust result is that municipalities with relatively high tax burden also show high service prices. One interpretation could be that municipalities are either financially sound or need to generate revenue wherever they are able to. Keep in mind that it is not known how much of the revenue out of administered prices for specific services is going to the municipalities. The focus of this analysis is on the burden for households, and prices are described descriptively. Very low adjusted R-squared values indicate that the basic model is not capable of explaining the differences in price levels very well. Other explanations for differences could be the quality of services, the efficiency of providers, or the intrinsic motivation of communal administrations. Additionally, prices can be affected by long-term decisions, such as creating reserves for depreciations or new infrastructure investments. Indicators for omitted variable biases do exist, especially for variables related to cantons.

No hint of economies of scale and capitalisation

No evidence was found for economies of scale or capitalisation of administered service prices. The absence of economies of scale in prices does not mean that in the production process none are given. This is quite a surprising result, but it is confirmed in a previous study. On the other hand, it seems obvious - assuming that households are neither fully rational nor completely informed - that administered prices do not capitalise in rents. The main reason is most likely the independence of income and therefore the relatively small amount to pay.

Uncertain institutional influence

The analysis of institutional or financial control in municipalities did yield interesting, but not fully reliable, results. Direct democracy on a communal level only has significant influence on the communally organised services of water supply and sewer water. Including the potential strength of finance commissions increases the explanatory power of the model and shows that municipalities with strong financial control have slightly lower administered prices. However, not all estimations and specifications confirmed this result with significant coefficients. Because the 'FinCom' index assigns identical values for all municipalities within a canton, the result is not robust towards specification modifications, and omitted variable biases are likely present.

Price setting mechanism remains a black box

Finally, the price-setting behaviour for basic services remains a black box. By relating the administered prices to municipality characteristics, some intuitions about how these prices are distributed over different municipalities can be provided. But key variables, such as production and administration efficiency, are very complicated to observe or instrument. The analysis dealing with administered prices is closed with two outlooks. As previously mentioned, in section 4.4.2, a somewhat hypothetical discussion about a possible role of administered prices in fiscal competition is outlined. In section 4.4.3, a very basic concept for a cost-of-living index for Swiss municipalities is presented.

4.4.2 Fiscal competition through administered prices?

To what extent might administered price levels play a role in fiscal competition? Based on the most important findings from this chapter, a possible role of administered prices in fiscal competition will be presented. The results show that administered prices cannot replace tax rates as a major instrument, but rather complement them in order to attract high-income households and deter those with low income. The discussion begins with a summary of the most important findings. Then, the incentives of municipalities, low- and high-income households will be discussed.

Firstly, user charges and administered prices should fulfil the cost recovery and benefits principle. Controlling the implementation of these principles is difficult. They do not imply any measure for production efficiency or competitiveness of prices. Secondly, competition for public services does not play any role in municipalities. Local monopolies are standard. Inter-communal competition is also non-existent. All service prices are administered on a communal level. Households are not aware of AP-levels because they do not care if the income is high and, if it is low, relocation seems very costly just to avoid high administered prices. Thirdly, administered prices are dependent on consumption and independent of income, so they can be compared to lump-sum taxes. Relatively, lump-sum taxes affect low- and medium-income households much more than high-income households. Administered prices especially burden large households with many members. Finally, no indication is found that administered prices capitalise in rents. As long as administered prices do not increase significantly, they probably will not have any influence on rents.

After outlining the initial position, the role of the players, their incentives and costs will be discussed. In this simplified framework, the players are municipalities and low- and high-income households.

Households try to minimise the aggregated cost of living. They have to make efforts to compare financial impacts of municipalities on their budget. Moving to a different municipality causes mobility cost. Households with high income are mainly concerned about (income) tax. Low-income households are not that influenced by taxes, but rather by rents and to some extent administered prices.

Municipalities, on the other hand, try to attract as many high-income households as possible to maximise revenue. The main tool to attract high-income households are low income tax rates, which may lead to high rents via capitalisation. If a municipality is able to engage in this strategy, it has the basic setting for attracting high-income households and deterring low-income ones (due to high rents). Additionally, municipalities can try to avoid low rents by refusing construction applications for low rent-apartments. Low tax rates may motivate additional investments in buildings and constructions, and overall a municipality should be fine in this limited context.

If, for whatever reason, this strategy cannot be utilised by a municipality, or the mechanics of capitalisation do not work, administered prices might come into play. High tax rates alone do not bother low-income households, as often they do not have to pay much or even any income tax. What might hurt the budgets of low-income households is an increase in the price for government services, because of its lump-sum tax characteristics. Additionally, the income tax burden could be reduced again through the higher revenue. Subsequently, the municipality can attract more high-income households.

Both the benefits and the cost recovery principles have to be respected. A municipality theoretically should not abuse administered prices for fiscal competition. Municipalities with very high API values exist for other reasons, but as of yet this has not been an issue. Another important observation in the empirical section is that high-income municipalities systematically have higher administered price levels. These mechanics might already work to some extent: breaking progressive tax systems by adding more lump-sum revenue, resulting in reduced revenue generation through progressive income tax.

To what extent this strategy is used by municipalities or could be applicable can be analysed in further studies. The amounts that have to be paid for basic services right now do not seem large enough (at least in most municipalities) to deter households. Of the underlying 324 municipalities, 21 have an API below 80 index points, and 20 have one above 120. If a great number of municipalities uses administered prices in the way discussed here, the standard deviation of the index increases. This might provoke public attention, followed by interference from politics and the courts.

In this outlook, the extent to which administered prices could be used in fiscal competition was discussed. The concept above is hypothetical and should illustrate that, especially for low income households, administered prices can be a serious burden. Considering that rents in Swiss cities continuously rise, this issue could be addressed.

4.4.3 Cost-of-living index for Swiss municipalities

The approach presented in part 4.2 measures costs for government services in Swiss municipalities. This idea could be extended to overall cost-of-living indexes for municipalities. Cost-of-living indexes for cities around the world already exist. They usually include consumption goods, but often exclude all government-related spendings such as taxes and fees. Across Swiss municipalities, price differences between consumption goods and services also exist.[12] However, the differences in spendings for these goods and services (except for gastronomy) between different municipalities have only a limited impact. Contrariwise, prices for government services, health care, rents and tax rates differ significantly and constitute a large part of a household's spendings. How can an index for cost of living be constructed such that the most important spendings of a household are included?

There are two basic methods that could be pursued for this construction. One is to create a random sample across households or citizens, including the quantities and quality of consumed goods and corresponding prices. Based on these data, either standard index formulas can be applied or a hedonic approach could be chosen. The problem is the very high cost of collecting these data. A sufficiently large random sample for each considered municipality is costly. Again, a second possibility is to work with fixed consumption profiles of households.

The consumption profiles in this analysis allow us to estimate prices for government services and rents. To add the most important financial aspect, the communal and cantonal income tax burden, the profiles have to be complemented by income. This results in a multidimensional profile for a household, containing the number of members, flat, income and service-specific consumption. For health care, the age of the people in the household should also be added. For the profiles and its dimensions, single distributions across Switzerland are known. The cost for an average or different specific households could be estimated. All basic data, including prices, are available. The main problem is that the joint frequency distributions of consumption between the individual dimensions of the profiles are often unknown. They need to be approximated or estimated.

Creating a cost-of-living index for Swiss municipalities would provide a key variable to compare the municipalities. It would put tax rates or rents in a complete context, including all other major spendings. Standard consumption

[12]Service prices, for example, for hair cuts, or gastronomy prices, vary widely. Even more importantly, consumption goods in stores have different prices across different municipality types. But for these goods, the differences are often compensated by higher quality. For example, the goods in food stores of a high-income municipality or a city centre are probably more expensive, but they usually are of better quality. Therefore, price differences for standard goods certainly exist, but these could probably be explained by quality differences.

goods could probably be neglected because their prices should not differ too much across municipalities. Based on such an index, the attractiveness of municipalities could be evaluated on a completely new level. As a side-product of the creation of such an index, online price-comparison portals could support household decision making by comparing different municipalities according to income, desired flat and people living in it. This tool could be extended with various features, such as time needed to go to work by car or public transport. As a result, households could compare municipalities precisely with regards to their preferences.

Chapter 5

General summary

The general summary consists of two parts. The most important results of each analysis and the important issues for further research are summarised in section 5.1. In the second section, 5.2, the general insights of all three projects are combined and implemented in simple heuristics. They support the decision making process in the selection of the optimal method for analysing a new system of specific tariff plans.

5.1 Key results

The general contribution of this thesis is the suggested solutions to problems with price measurement, particularly in how to compare service providers that offer (multiple) tariff plans. It is shown how prices can be compared efficiently among several tariff plans from different providers. This issue rarely finds a place in the scientific literature. Technical manuals of statistical offices or other organisations, if available, predominantly suggest the use of consumption profiles to compare service prices.

Though all analysed prices result from tariff plans, the three projects are quite independent, and thus the major contributions are contained in the specific applications. For mobile communication services and public transport, two innovative index concepts are suggested and empirically tested. In the context of administered prices, standard consumption profiles are used to compare service prices. There, the relevant contribution is the economic analysis of service prices in Swiss municipalities. The most important findings and issues for further research of each project are summarised below. To avoid redundancy with the general introduction in chapter 1 and the summaries of each specific chapter, this section focuses only on the most important points.

Hedonic price indexes for mobile communication

By applying hedonic price indexes to compare tariff plans of mobile communication providers, all characteristics of the extremely diverse contracts are consistently implemented in the price comparison. The presently used consumption profile methods are not capable of doing so, and they ignore major characteristics, which results in biased price comparisons.

As this is a first application of hedonic price indexes for mobile communication, different model specifications are estimated with several methods. Because consumption is dependent on the tariff plans, the double-imputed indexes use symmetric index formulas to treat all providers equally. All resulting indexes indicate that Swisscom has significantly lower implicit prices than Orange for the given sample. This contradicts official statistics. Possible reasons are that Orange consumers are not in efficient tariff plans, Swisscom offers more attractive tariff plans for students or Orange adapts its tariff plans to the consumption profiles of the Federal Office of Communications. For further research, non-parametric model specifications might be particularly interesting to improve the prediction accuracy. Additionally, several practical issues give rise to important open questions, such as determining optimally the discount on the phone price.

The kilometer price index for public transport

The kilometer price index for public transport describes the implicit price for an averagely consumed kilometer with a specific provider. The concept is straightforward and easily communicable to a broad public. Currently used price indexes for public transport in Switzerland use profiles and compare explicit prices of tickets. These methods are undocumented, and they suffer from the same problems as all other indexes based on profiles.

In the results, the presented kilometer price index estimates implicit price increases to be lower than the other methods do. In years without any tariff change, implicit prices may even fall, which is not perceived at all by the public. More than 50% of all kilometers are travelled by people possessing a GA travelcard. Though its explicit price has been raised significantly, the implicit kilometer price increased by only 4% between 2007 and 2011. The major reason for this observation is that consumers travel more with the same GA tariff plan, mainly because the quality and speed of connections increased. These increases are implemented in the index and consequently result in lower implicit kilometer prices. Ticket types with smaller weights in the index contributed more to the general implicit price increase measured by the KMI, even though their explicit prices were not raised that much. In further applications of this concept, one should mainly invest in the data structure and, separate first- and second-class tickets into different accounts.

Administered prices of basic services in Swiss municipalities

Prices for electricity, waste management, water supply and sewer water services are paid by every household each year. A representative two-person household pays in average slightly more than 1′000 Swiss francs for these four services. The services are provided by local monopolists, and the prices are administered by governments. Because the prices for four different services among 324 Swiss municipalities are compared, the profile method is applied. Three standardised households are used to determine the profiles and measure service prices for different consumption intensities. The resulting index shows significant differences in service prices across municipalities. Because the prices are administered and should respect the benefits as well as the cost recovery principles, these differences are analysed.

The service price differences are explained by several municipality characteristics. The most robust result is that municipalities with a high tax burden usually also show high service prices. In addition, the municipalities in cantons with strong financial control tend to show lower administered prices. Both results are heavily dependent on cantonal clusters and should be interpreted cautiously. There is no sign that economies of scale result in lower service prices or that these service prices capitalise in rents. This analysis provided an alternative perspective on user charges, which generate part of non-tax government revenue. In further research, particularly the cantonal variables omitted in the estimations should be investigated and discussed. To compare municipalities with regard to several fiscal and financial variables from a household perspective, a cost-of-living index, including tax rates, rents, education and healthcare costs could be constructed. As a result, municipalities could be evaluated precisely by including these important variables jointly. Additionally, this concept could be used to create a website to support household decision making about where to live, according to household type, income and workplace.

5.2 Heuristics to select the optimal method

Which method should be applied to analyse prices from a specific new system of tariff plans? This question is answered by summarising the most important general insights of all three projects combined. As a result, the choice is mainly dependent on three factors, namely the characteristics of the tariff plans, the purpose of the analysis and the available data.

Problems caused by tariff plans

Tariff plan systems pose problems in standard price statistics when trying to compare service providers. That services can be purchased via different tariff plans is the central issue. This results in different costs or prices for the consumption of identical services. Additionally, complex and diverse tariff plan specifications, such as flat rates or special discounts, often pose immense problems because the resulting service prices are independent of consumption. The aim of a price comparison should be to compare implicit prices for actually consumed services, not to compare explicit prices that are not related to actual consumption. The presented approaches analyse prices resulting from tariff plans by adjusting price indexes for actual quantities consumed, corresponding quality and prices paid.

Identifying explicit and implicit prices

For this purpose, explicit and implicit prices have to be identified and distinguished for the given tariff plans and providers. When implicit unit prices can be identified and estimated, several price index concepts are applicable. If implicit unit prices cannot be identified or estimated, the use of consumption profiles is required. Determining service prices for consumption profiles is almost always a feasible solution. The downside is, as discussed throughout the entire thesis, that the resulting prices may lack important aspects of the tariff plans, which results in questionable rankings of provider prices. For example, in the mobile communication project, the profiles did not allow the inclusion of the discounts for students, which are a significant component of the service prices.

Selecting the optimal method

If implicit unit prices can be estimated, the choice of the optimal method is dependent on the purpose of the analysis, the characteristics of the tariff plans and the available data (or the budget for sampling). If the purpose is a simple measure that has to be stable and easily communicated, a standard price index formula, as in the public transport chapter, is preferable. If a more extensive analysis is planned, or if the characteristics of the tariff plans are complex (for example, when different units are contained in a service, such as in mobile communication), the hedonic approach is very promising. However, in reality, sampling cost or available data are usually the limiting factors.

Data as resource and constraint

If data of single observations are not available or the general quality is inferior, it may be difficult or even impossible to estimate implicit unit prices. In this case, one has to rely again on consumption profiles. Despite all of their problems, consumption profiles have two major advantages. First, if tariff plans for several services are analysed, as in chapter 4, the other approaches can result in overly complicated price comparisons. The results may be difficult to interpret or be influenced by the limiting assumptions that were needed to obtain them.

The second advantage of fixed consumption profiles is that the corresponding prices can be determined under any circumstances, especially when no data is available and the budget to generate new data is limited.

Data from service providers

As in chapter 3, which addressed public transport, data about aggregated revenue and consumption from providers might be available. Or even better, they could have consumer-specific observations on hand; for example, mobile communications service providers have monthly phone bills. The advantage of this scenario is obviously that the cost of data generation is minimal. The downside is that aggregated consumption is usually estimated, and these estimations may contain problems. Additionally, the data are provided by the provider whose prices are analysed, so there may be conflicts of interests.

Accuracy of the three applied methods

In this thesis, only three methods were presented. There is no need to mention that other approaches exist for comparing prices resulting from tariff plans. From the applied methods, the hedonic price indexes yield theoretically accurate results if the model is specified correctly. However, the method requires good data quality. Additionally, the approach requires a sufficiently large sample. Moreover, the concept for public transport results in a theoretically unbiased and accurate estimator for the price of an averagely travelled kilometer. The problem is again on the data side. If one cannot ensure that the estimation quality of aggregated revenue and consumption is good, profiles may be a more reliable and stable measure for comparing prices.

Therefore, these two concepts are theoretically accurate estimators for provider prices. However, they depend heavily on data quality and are quite sensitive. The third approach, the profile method, is the opposite. Theoretically, it is not necessarily an unbiased estimator. It is applied for basic services because there is only one tariff per municipality and service. In this case, no strict assumptions about the consumer behaviour are required. The profile method is theoretically not very elegant. But practically, it is very robust towards data because prices for profiles can always be collected and compared. To sum up, if data quality is bad, using a 'fancy' method might yield less accurate results than profiles do.

Appendix A

A.1 Mobile communication

A.1.1 Average unit prices and the constant

In the estimations of subsection 2.3.2, the constant is always significantly different from zero. The constant can be interpreted as the basic subscription price for a certain provider, but it does not correspond to a consumption unit. The constant is always relatively large. In contrast, the estimated coefficients are marginal unit prices that are often estimated smaller than expected or not significantly different from zero. This is caused by the structures of contracts for students, which contain flat rates for calls, text messages and data. Contracts with high fixed cost and no marginal cost do obviously influence the magnitude of the constant upwards. In this part of the appendix, average unit prices are estimated to evaluate how the invoiced amount is distributed in average on consumed units. To obtain average unit prices, models without a constant are estimated.

The average invoiced amount is about 55 Swiss francs (CHF), whereas the constants are estimated between 25 and 52 CHF in the linear specifications. Average unit prices from providers are presented by estimating all model specifications with a suppressed constant. The invoiced amount is regressed exclusively on consumed units. As a result, the coefficients can be interpreted as average unit prices. In the linear specification, they are scaled in CHF. However, suppressing the constant has econometric consequences. All estimated coefficients are biased, so the estimates give only an idea of the magnitude of an average unit price. The adjusted R-squared no longer denotes the proportion of variance explained compared to a model containing only a constant. It is compared to white noise, which explains the high adjusted R-squared.

All estimations are carried out again and reported in the following tables:

- Table A.3: Specifications with single variables
- Table A.4: Specifications with grouped variables
- Table A.5: Specifications without influential observations, grouped variables
- Table A.6: Specifications without influential observations, single vari-

ables

- Table A.7: Model estimation for index construction

The estimations with grouped variables are used to describe the prices. The descriptions should give an idea of the range of average unit prices from both providers. Generally, Orange's prices are more sensitive to estimation variants.

- The average minute price (without roaming) is estimated between 0.03 and 0.11 CHF.
- An average text message costs between 0.06 and 0.12 CHF.
- A megabyte costs from 0.02 to 0.05 CHF.
- Roaming minute unit prices are estimated at between 0.12 and 1.21 CHF.
- Not enough observations contain roaming text messages, so their unit prices widely depend on the specification and estimation method. This also holds for roaming data.
- The phone discount coefficient is estimated at between 0.75 and 1.67 CHF.

The phone discount is the most interesting variable in these estimations with a suppressed constant. It is quite stable over all estimations. Because the variable is scaled in CHF, the coefficient can be interpreted as how much of the discount is paid back to the provider per month. A coefficient of 1 would signify that the discount is paid back exactly. The estimated coefficients are around 1 when there is no constant in the model specification. This indicates that the fixed cost could be explained by a consumption unit, namely the phone discount, which corresponds to the reality of mobile communication contracts. Discounts on phones are usually linked to the magnitude of the fixed cost of a contract.

The principle goal of a hedonic price index is to obtain accurate and unbiased predictions. Therefore, specifications with constants are used in chapter 2. Whether the phone discount can replace the constant, and reasonable predictions can still be obtained, is an open question. Certainly, suppressing the constant shows that the phone discount variable is able to explain much more than was apparent in the genuine estimations.

In both of the following tables, indexes are constructed based on linear models with grouped variables and a suppressed constant, see table A.7. The results can be compared to those in subsection 2.3.3. The specifications with the biased unit prices tend to estimate rather high relative price levels, see tables A.1 and A.2. How this result should be interpreted is an issue for further research.

Table A.1: Indexes with base period t

	Fisher			Törnqvist		
	M	S	O	M	S	O
Q3.12	100.00	99.95	109.99	100.00	99.99	102.96
Q4.12	100.00	97.63	146.71	100.00	95.92	115.57
Q1.13	100.00	98.31	131.09	100.00	99.01	130.26

Note: Swisscom (S) and Orange (O) prices are compared to the entire sample or market (M). All price comparisons are made within one of the quarterly periods, Q3.12, Q4.12 and Q1.13. The Fisher index is reported on the left and the Törnqvist index on the right.

Table A.2: Indexes with base period 0

	Fisher			Törnqvist		
	M	S	O	M	S	O
Q3.12	100.00	99.95	109.99	100.00	99.99	102.96
Q4.12	78.36	76.50	114.96	87.27	83.71	100.85
Q1.13	81.38	80.00	106.68	90.63	89.73	118.05

Note: Swisscom (S) and Orange (O) prices are compared to the entire sample or market (M). All price comparisons are relative to the entire market (M) in Q3.12, thus price development over time is observable. The Fisher index is reported on the left and the Törnqvist index on the right.

Table A.3: Specifications with single consumption variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Minutes fix net	0.129**	−0.047	0.010***	−0.002	0.023***	−0.007	1.537	3.335
	(0.039)	(0.060)	(0.003)	(0.003)	(0.006)	(0.008)	(1.385)	(2.498)
Minutes mobile on	0.004	0.072	0.003***	0.005*	0.005*	0.014*	−0.457	−0.321
	(0.013)	(0.045)	(0.001)	(0.003)	(0.002)	(0.006)	(1.103)	(1.998)
Minutes mobile off	0.007	0.546***	−0.013*	0.015**	−0.021	0.055***	4.754**	9.031***
	(0.083)	(0.084)	(0.005)	(0.005)	(0.013)	(0.012)	(1.448)	(2.212)
SMS	0.066**	0.057	0.007***	0.007***	0.015***	0.015**	2.728*	1.137
	(0.024)	(0.036)	(0.002)	(0.002)	(0.004)	(0.005)	(1.294)	(1.904)
MMS	0.255	0.823	−0.017	0.010	−0.018	0.046	4.361*	16.710***
	(0.407)	(1.445)	(0.026)	(0.081)	(0.062)	(0.204)	(1.883)	(4.824)
MB	0.023***	0.033***	0.001***	0.002***	0.002***	0.006***	5.068***	3.539**
	(0.002)	(0.008)	(0.000)	(0.000)	(0.000)	(0.001)	(0.602)	(1.135)
CH minutes roaming	0.046	0.077	−0.002	−0.004	−0.002	−0.001	4.084	2.081
	(0.033)	(0.324)	(0.002)	(0.018)	(0.005)	(0.046)	(2.368)	(3.592)
CH SMS roaming	0.183	1.099***	0.053*	0.038**	0.100*	0.125***	−5.507**	6.348*
	(0.321)	(0.211)	(0.021)	(0.012)	(0.049)	(0.030)	(2.018)	(2.851)
Roaming minutes	2.066***	5.006***	0.069*	0.044	0.230**	0.287*	14.385***	11.051*
	(0.483)	(0.874)	(0.031)	(0.049)	(0.074)	(0.124)	(2.991)	(4.568)
Roaming SMS	0.551**	0.637	0.034**	0.012	0.088**	0.048	7.129***	5.989
	(0.176)	(0.516)	(0.011)	(0.029)	(0.027)	(0.073)	(1.799)	(4.895)
Roaming MMS	19.311*	−45.464	0.770	−2.716	2.368	−7.228	5.625	12.450
	(9.268)	(28.739)	(0.596)	(1.609)	(1.421)	(4.067)	(10.042)	(25.166)
Roaming MB	0.945**	1.155**	−0.005	0.016	0.014	0.085	16.256***	16.708***
	(0.284)	(0.418)	(0.018)	(0.023)	(0.044)	(0.059)	(4.575)	(4.521)
Phone discount	1.550***	0.665**	0.138***	0.087***	0.321***	0.188***	−0.250	−0.441
	(0.204)	(0.213)	(0.013)	(0.012)	(0.031)	(0.030)	(0.201)	(0.238)
N	215	115	215	115	215	115	215	115
adj. R-squared	0.852	0.872	0.827	0.880	0.846	0.885	0.906	0.898
Reset	73.556***	45.088***	388.851***	275.911***	277.346***	146.289***	1.796	12.522***
Jarque-Bera	87.358***	1.084	3.576	1.594	3.284	0.699	416.536***	73.710***
Breusch-Pagan	66.376***	30.391**	48.729***	14.721	57.136***	14.213	48.315***	39.693***

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera test with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

Table A.4: Specifications with grouped consumption variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Minutes	0.030**	0.062*	0.003***	0.003*	0.005***	0.007**	2.423*	8.278***
	(0.011)	(0.025)	(0.001)	(0.001)	(0.001)	(0.002)	(1.035)	(1.916)
Text messages	0.061***	0.116*	0.005***	0.009***	0.010***	0.017***	2.221	2.896
	(0.018)	(0.046)	(0.001)	(0.002)	(0.002)	(0.004)	(1.220)	(2.067)
MB	0.024***	0.049***	0.001***	0.003***	0.002***	0.006***	5.219***	2.180
	(0.002)	(0.009)	(0.000)	(0.000)	(0.000)	(0.001)	(0.588)	(1.279)
Roaming minutes	0.122***	1.208***	0.000	0.016	0.004	0.055*	10.910***	10.985***
	(0.028)	(0.258)	(0.002)	(0.012)	(0.003)	(0.024)	(1.945)	(2.643)
Roaming text	0.751***	−0.140	0.044***	−0.013	0.088***	−0.031	5.675**	1.733
	(0.178)	(0.640)	(0.011)	(0.029)	(0.021)	(0.059)	(1.704)	(4.922)
Roaming MB	1.300***	1.979***	0.000	0.032	0.022	0.102*	17.569***	26.837***
	(0.286)	(0.522)	(0.018)	(0.023)	(0.034)	(0.048)	(4.240)	(4.598)
Phone discount	1.667***	0.749**	0.154***	0.086***	0.284***	0.152***	−0.224	−0.423
	(0.202)	(0.262)	(0.013)	(0.012)	(0.024)	(0.024)	(0.204)	(0.243)
N	215	115	215	115	215	115	215	115
adj. R-squared	0.833	0.774	0.811	0.865	0.826	0.856	0.895	0.870
Reset	40.971***	33.663***	314.589***	189.415***	252.089***	113.972***	2.481	2.583
Jarque-Bera	362.233***	13.675**	1.576	2.153	0.418	1.184	444.834***	86.641***
Breusch-Pagan	15.583*	41.736***	60.851***	11.313	50.160***	12.916*	27.926***	27.504***

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera test with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

Table A.5: Removing influential observations, grouped variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Minutes	0.036***	0.113***	0.003***	0.005***	0.005***	0.012***	2.494***	8.523***
	(0.010)	(0.024)	(0.001)	(0.001)	(0.001)	(0.003)	(0.664)	(1.293)
Text messages	0.075***	0.101**	0.013***	0.008***	0.023***	0.015***	2.502**	3.980**
	(0.018)	(0.035)	(0.002)	(0.002)	(0.003)	(0.004)	(0.802)	(1.493)
MB	0.027***	0.028***	0.001***	0.003***	0.002***	0.005***	4.282***	0.984
	(0.003)	(0.008)	(0.000)	(0.000)	(0.000)	(0.001)	(0.404)	(0.901)
Roaming minutes	0.153***	0.920**	0.000	0.032	0.003	0.088*	7.757***	6.836***
	(0.039)	(0.318)	(0.002)	(0.018)	(0.003)	(0.035)	(1.553)	(2.001)
Roaming text	0.967***	−0.782	0.081***	−0.036	0.159***	−0.038	4.084***	0.154
	(0.277)	(1.359)	(0.020)	(0.032)	(0.038)	(0.167)	(1.069)	(6.471)
Roaming MB	0.881	6.969***	−0.014	0.081	0.003	0.295	20.887***	27.668***
	(0.829)	(1.312)	(0.035)	(0.082)	(0.035)	(0.160)	(3.769)	(3.615)
Phone discount	1.528***	0.822***	0.126***	0.080***	0.234***	0.142***	0.050	−0.295
	(0.181)	(0.193)	(0.013)	(0.012)	(0.024)	(0.023)	(0.140)	(0.171)
N	196	101	201	108	201	106	193	98
adj. R-squared	0.858	0.849	0.844	0.871	0.856	0.871	0.941	0.934
Reset	46.784***	30.215***	453.230***	215.809***	290.452***	139.408***	1.238	7.725**
Jarque-Bera	9.488**	1.958	3.862	3.256	1.085	1.781	19.304***	0.574
Breusch-Pagan	2.917	4.971	31.772***	10.036	22.144**	9.869	3.010	4.613

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera test with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

Table A.6: Removing influential observations, single variables

	lin S	lin O	log S	log O	BC S	BC O	dmp S	dmp O
Minutes fix net	0.155***	−0.010	0.011***	−0.002	0.021***	−0.004	2.198*	1.329
	(0.029)	(0.071)	(0.002)	(0.003)	(0.004)	(0.006)	(0.877)	(1.525)
Minutes mobile on	0.005	0.149**	0.002*	0.008**	0.002	0.017**	−0.142	1.617
	(0.010)	(0.045)	(0.001)	(0.003)	(0.002)	(0.006)	(0.721)	(1.198)
Minutes mobile off	0.028	0.538***	−0.008	0.021***	−0.011	0.051***	4.522***	8.851***
	(0.072)	(0.090)	(0.006)	(0.006)	(0.011)	(0.011)	(0.924)	(1.334)
SMS	0.123***	0.039	0.013***	0.006**	0.024***	0.009*	1.651	3.414**
	(0.023)	(0.032)	(0.002)	(0.002)	(0.003)	(0.004)	(0.885)	(1.213)
MMS	0.139	1.879	0.004	0.018	0.014	0.324	2.571*	10.138**
	(0.313)	(3.553)	(0.026)	(0.084)	(0.047)	(0.619)	(1.202)	(3.437)
MB	0.025***	0.024**	0.001***	0.002***	0.002***	0.004***	5.063***	1.461
	(0.003)	(0.007)	(0.000)	(0.000)	(0.000)	(0.001)	(0.414)	(0.740)
CH minutes roaming	0.017	0.200	−0.002	−0.006	−0.004	−0.019	6.935***	1.056
	(0.039)	(0.573)	(0.003)	(0.034)	(0.006)	(0.069)	(1.769)	(2.227)
CH SMS roaming	0.257	1.663***	0.069*	0.075**	0.093*	0.170***	−4.663***	8.593***
	(0.233)	(0.435)	(0.029)	(0.024)	(0.042)	(0.047)	(1.307)	(1.770)
Roaming minutes	2.949***	1.451	0.063	−0.007	0.234	0.121	7.954**	2.582
	(0.830)	(2.065)	(0.067)	(0.077)	(0.127)	(0.227)	(2.399)	(2.954)
Roaming SMS	0.673**	−0.379	0.055*	0.004	0.081*	0.008	4.722***	5.729
	(0.203)	(1.276)	(0.023)	(0.032)	(0.031)	(0.060)	(1.150)	(4.076)
Roaming MMS	21.987	−67.380	1.075	−5.374*	3.020	−10.952*	10.841	19.083
	(17.559)	(46.627)	(1.037)	(2.175)	(1.904)	(4.372)	(6.279)	(14.401)
Roaming MB	0.212	2.100	−0.031	0.046	−0.074	0.096	8.822*	16.472***
	(0.787)	(3.057)	(0.062)	(0.064)	(0.118)	(0.138)	(4.307)	(3.389)
Phone discount	1.276***	0.782***	0.119***	0.083***	0.217***	0.150***	0.100	−0.066
	(0.164)	(0.189)	(0.013)	(0.012)	(0.025)	(0.023)	(0.141)	(0.149)
N	191	99	195	106	193	104	196	100
adj. R-squared	0.894	0.888	0.853	0.885	0.867	0.893	0.949	0.958
Reset	47.419***	40.752***	536.498***	229.876***	348.727***	153.304***	2.126	5.881**
Jarque-Bera	0.841	0.128	5.268	0.673	4.189	0.257	20.544***	0.048
Breusch-Pagan	16.236	14.643	32.992**	12.386	30.608**	14.001	17.882	11.123

Note: The dependent variable in all estimations is the monthly invoiced amount. Different model specifications are estimated, as indicated in the header: lin (Linear), log (Semi-log), BC (Box-Cox) and dmp (Decreasing marginal price). All coefficients are estimated by OLS for Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared, RESET test with null hypothesis 'well specified', Jarque-Bera test with null hypothesis 'normal residual distribution' and stud. Breusch-Pagan test with null hypothesis 'no heteroscedasticity' are in the second part of the table.

Table A.7: Model estimation for index construction

	Q3.12 M	Q3.12 S	Q3.12 O	Q4.12 M	Q4.12 S	Q4.12 O	Q1.13 M	Q1.13 S	Q1.13 O
Minutes	0.032	0.028	0.076*	0.047**	0.034*	0.089*	0.027	0.023	0.097*
	(0.021)	(0.025)	(0.034)	(0.016)	(0.015)	(0.039)	(0.016)	(0.015)	(0.044)
Text messages	0.187***	0.226***	0.114	0.093***	0.067**	0.082	0.039	0.017	0.071
	(0.042)	(0.053)	(0.065)	(0.026)	(0.024)	(0.078)	(0.025)	(0.021)	(0.070)
MB	0.023***	0.019**	0.054**	0.024***	0.023***	0.048**	0.011*	0.014***	0.012
	(0.005)	(0.006)	(0.016)	(0.004)	(0.003)	(0.014)	(0.005)	(0.004)	(0.012)
Roaming minutes	1.629***	2.395***	0.713	0.131***	0.105**	3.039***	0.003	0.085	0.187
	(0.426)	(0.504)	(0.738)	(0.038)	(0.034)	(0.787)	(0.048)	(0.048)	(0.267)
Roaming text	0.161	0.236	−0.472	0.744	0.968*	−1.557	1.257***	1.059***	6.300
	(0.256)	(0.258)	(0.790)	(0.427)	(0.377)	(1.876)	(0.323)	(0.264)	(7.602)
Roaming MB	1.792*	1.027	6.391**	0.961**	1.091***	1.648	5.833***	2.406	3.008
	(0.712)	(0.709)	(1.827)	(0.288)	(0.309)	(0.864)	(1.085)	(1.254)	(10.197)
Phone discount	1.191***	0.963*	0.713	1.318***	1.614***	0.472	2.108***	2.318***	1.552**
	(0.255)	(0.369)	(0.380)	(0.198)	(0.283)	(0.359)	(0.239)	(0.308)	(0.458)
N	109	66	43	151	99	49	75	50	23
adj. R-squared	0.807	0.849	0.809	0.798	0.858	0.795	0.861	0.894	0.943

Note: The dependent variable in all estimations is the monthly invoiced amount. All estimations are for a quarter (Q) and a provider: Entire market (M), Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N) and the adjusted R-squared are reported in the second part of the table.

A.1.2 Comparison to official statistics

With the OECD profile method, see Federal Office of Communications (2013), minimal cost contracts for specified consumption profiles are compared across providers and over time. These consumption profiles contain a certain number of calls, divided among types, as well as a certain number of SMS sent. Data traffic (until 2013), roaming and discounts on phone prices are not included.

To compare the official statistics to the hedonic indexes, consumption profiles must first be adjusted. Because it is not the number of minutes called that is used, but rather call frequencies, these frequencies have to be transformed into amounts. Based on the underlying data, an average call is approximately 2.5 minutes long. The number of calls is therefore multiplied by 2.5. Additionally, MB were added to the consumption profiles according to the distribution of the underlying sample, as shown in table A.8.[13] The values chosen correspond to the quartiles of the sample from this project, with roughly 100 MB equal to the first, 250 to the second or median and 500 to the third quartile. The quantities of MB used by the Federal Office of Communications (2013) do not line up at all with the distribution in this sample. Roaming units and phone discounts are excluded to maintain the possibly highest level of similarity to the genuine profiles of the Federal Office of Communications (2013).[14]

After defining consumption profiles, two strategies to predict prices using the so-called characteristics method are considered. With the characteristics method, unit prices are estimated as they are for double-imputation. Then, prices are not predicted for all observations, but only for a predefined consumption vector.

As a first possibility, estimations can be made based on observations within a certain consumption intensity. Recall that unit prices are dependent upon consumption intensities. Therefore, for small, medium and strong consumption, unit prices are estimated separately. A second possibility is to estimate overall

[13] In the latest price comparison, the Federal Office of Communications (2013) added MB to the profiles because this is recommended in the most recent manual of the OECD (2012). Before 2013, the quantity of MB in all profiles was equal to zero.

[14] An indicator for the phone discount could be easily added to the OECD consumption profiles. This would make the price comparisons much more realistic. Additionally, a separate roaming profile could be constructed.

Table A.8: Complemented consumption profiles

	Small	Medium	Large
Minutes	75	100	300
Text	100	140	225
MB	100	250	500
Roaming minutes	0	0	0
Roaming text	0	0	0
Roaming MB	0	0	0
Phone discount	0	0	0

Sources: Federal Office of Communications (2013), extended.

unit prices using all observations for every provider to then predict invoiced amounts. In this analysis, the first method does not yield reasonable results. The second method does to some extent, but they are not very reliable.

For the first strategy, profile-specific unit prices are estimated as shown in table A.9. The sub-samples to estimate unit prices were formed as follows. For the small consumption profile, all observations with fewer than 100 minutes and 250 MB were selected, so they showed less consumption than with the medium profile. SMS were not used as constraint, first because the number used for the profiles seems very high relative to the sample distribution. Secondly, three constraints would be too restrictive, and only few observations would be left. For the estimation of the prices for the medium profile, all observations with minutes and MB consumption between the small and large profiles are selected. In the sub-sample for the large profile, all observations with more minutes and MB than in the medium profile are included. The linear specification with grouped variables is used.

Surprisingly, estimating according to consumption profiles and not time periods yields worse estimation results. This is surprising because in a given consumption interval, prices might be related more linearly to consumption. However, similarly, this could have been expected because the number of observations is quite small in most estimations. Many coefficients are estimated as negative or not significant.

Due to the poor estimation quality, the resulting indexes obtain unrealistic results, as shown in table A.10. Prices are predicted for the predefined consumption profiles in table A.8 above. This way of creating an index by pre-

Table A.9: Profile-specific model estimation

	M small	S small	O small	M medium	S medium	O medium	M large	S large	O large
Constant	37.273***	31.272***	30.863**	39.312***	24.314*	46.459***	44.608***	34.041***	66.993***
	(5.411)	(6.041)	(9.380)	(6.872)	(10.214)	(8.059)	(6.797)	(8.842)	(18.620)
Minutes	0.144	0.164	0.308*	0.067*	0.089*	0.083*	−0.004	0.006	0.008
	(0.079)	(0.101)	(0.130)	(0.028)	(0.035)	(0.041)	(0.015)	(0.019)	(0.028)
Text messages	0.010	0.048	0.111	0.004	−0.007	−0.010	−0.004	−0.049	0.034
	(0.057)	(0.075)	(0.083)	(0.012)	(0.013)	(0.025)	(0.031)	(0.038)	(0.054)
MB	−0.022	0.022	−0.062	−0.011	−0.030	0.006	0.020***	0.023***	−0.006
	(0.030)	(0.033)	(0.051)	(0.014)	(0.017)	(0.019)	(0.003)	(0.003)	(0.015)
Roaming minutes	0.573***	2.544***	0.941**	0.089**	−0.014	0.983***	−0.005	−0.039	0.788
	(0.160)	(0.445)	(0.287)	(0.028)	(0.235)	(0.270)	(0.187)	(0.186)	(0.552)
Roaming text	0.160	0.127	−1.838	−0.013	0.187	−1.538	−0.671	0.132	−2.507
	(0.194)	(0.168)	(1.715)	(0.355)	(0.302)	(2.141)	(1.128)	(1.053)	(6.784)
Roaming MB	−17.645*	−102.142***	1.618	3.518***	6.790	3.395***	1.895***	1.630***	6.050***
	(6.913)	(19.191)	(8.120)	(0.813)	(9.771)	(0.804)	(0.457)	(0.441)	(1.554)
Phone discount	0.112	−0.891*	0.196	0.371*	1.561***	−0.335	0.152	0.601	−0.691
	(0.214)	(0.370)	(0.317)	(0.187)	(0.348)	(0.228)	(0.300)	(0.514)	(0.398)
N	118	69	45	123	58	65	110	60	50
adj. R-squared	0.282	0.553	0.236	0.509	0.788	0.334	0.641	0.799	0.270

Note: The dependent variable in all estimations is the monthly invoiced amount. All OLS estimations are for small, medium or large consumption profiles and a firm: Entire market (M), Swisscom (S) and Orange (O). Significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Estimated standard errors are reported in parentheses below every estimate. The number of observations (N) and the adjusted R-squared are reported in the second part of the table.

dicting prices for constructed consumption vectors is called the characteristics method.

Table A.10: Predicted invoiced amounts in CHF, profile-specific prices

	Small	Medium	Large
Market	46.93	43.92	52.58
Swisscom	50.58	24.60	36.37
Orange	58.90	54.87	74.14

The predicted prices are lower for the medium profile for all three providers. This result cannot be justified. It indicates negative marginal unit prices, which is not realistic. Roaming and especially the discount on phones are not in the consumption vector, and this may have disturbed this attempt to use the characteristics method. The main problem is the estimations of unit prices and the resulting coefficients. A larger sample might help a great deal.

The second strategy is to estimate unit prices that are not dependent on consumption intensities. The problem with this approach is that unit prices are heavily dependent on the contract and on the consumption intensity. Predicting prices for specific consumption profiles with overall unit prices is odd. Because the 'better' strategy above yields unrealistic results, this second approach is nevertheless carried out. The unit prices used to predict invoiced amounts are reported in table 2.7. The prices for the entire market in the three quarters are estimated separately and are not reported.

In the results, seen in table A.11, prices now increase as expected, along with consumption intensity. Orange prices are predicted to be about 25% to 30% above the average. Swisscom prices are around 8% to 9% lower. The indexes of the Federal Office of Communications (2012) report Orange prices to be lower for the low and medium consumption profiles, whereas Swisscom prices are lower for the large consumption profile. This difference may have been caused by several factors. However, the OECD method cannot include demographic discounts in contracts, such as those as for students. This could be the main reason that Swisscom is also cheaper in the low-consumption profiles in this analysis.

The main problem with using the characteristics method in this analysis is the small sample size. Because only a few observations contain roaming units, the

Table A.11: Predicted invoiced amounts in CHF, constant unit prices

	Small	Medium	Large
Market	43.29	46.62	53.72
Swisscom	39.08	42.66	49.06
Orange	56.17	58.52	67.50

corresponding estimated coefficients obtain extreme values. The consumption profiles do not contain any roaming units. To create hedonic price indexes with the characteristics method, two requirements have to be fulfilled. Firstly, the sample size needs to be much larger. Secondly, profiles have to contain values for all consumption units used in the specification of the hedonic function. Otherwise, the predicted invoiced amounts are not reliable.

A.2 Administered prices

A.2.1 API for 324 municipalities

Table A.12 shows a complete list of the administered price indexes with and without electricity for every municipality (API, API$_{-e}$), calculated as shown in subsection 4.2.3. Additionally, the indexed prices for every service are reported, namely electricity (EL), waste management (WM), sewer water (SW) and water supply (WS). These four indexes are the prices for an average household, as described in subsection 4.2.2. The arithmetic mean of all indexes is equal to 100 points. The indexes are for 2012.

Table A.12: Complete API

	Municipality	Canton	API	API$_{-e}$	EL	WM	SW	WS
1	Lugano	TI	61.56	38.44	86.96	0.00	28.61	86.67
2	Oberentfelden	AG	71.93	65.16	79.36	0.00	109.49	81.29
3	Spreitenbach	AG	72.32	67.45	77.67	101.83	59.38	42.46
4	St. Moritz	GR	72.34	40.86	106.93	0.00	85.64	32.70
5	Stans	NW	72.91	53.84	93.86	0.00	122.92	32.27
6	Fislisbach	AG	73.91	69.17	79.12	111.00	53.98	44.54
7	Collombey-Muraz	VS	74.69	39.92	112.89	0.00	59.38	58.07
8	Gland	VD	75.01	46.88	105.92	0.00	64.78	73.53
9	Dielsdorf	ZH	75.33	68.99	82.29	105.30	35.37	69.60
10	Volketswil	ZH	76.80	71.81	82.29	123.04	52.21	42.71
11	Risch	ZG	77.12	60.40	95.48	0.00	95.61	81.67
12	Au (SG)	SG	77.15	65.19	90.28	87.42	51.28	58.38
13	Schlieren	ZH	78.22	74.52	82.29	105.28	75.06	43.81
14	Bernex	GE	78.65	69.54	88.66	0.00	75.25	131.49
15	Carouge (GE)	GE	78.65	69.54	88.66	0.00	75.25	131.49
16	Chêne-Bougeries	GE	78.65	69.54	88.66	0.00	75.25	131.49
17	Lancy	GE	78.65	69.54	88.66	0.00	75.25	131.49
18	Meyrin	GE	78.65	69.54	88.66	0.00	75.25	131.49
19	Onex	GE	78.65	69.54	88.66	0.00	75.25	131.49
20	Thônex	GE	78.65	69.54	88.66	0.00	75.25	131.49
21	Vernier	GE	78.65	69.54	88.66	0.00	75.25	131.49
22	Bremgarten (AG)	AG	80.10	68.53	92.80	108.70	64.78	33.24
23	Savièse	VS	80.15	68.58	92.86	86.22	53.75	67.25
24	Conthey	VS	80.32	68.89	92.86	89.80	51.78	66.83
25	Monthey	VS	80.36	71.79	89.77	96.33	53.18	67.78
26	Chêne-Bourg	GE	80.44	72.96	88.66	0.00	84.97	131.49
27	Collonge-Bellerive	GE	80.44	72.96	88.66	0.00	84.97	131.49
28	Genève	GE	80.44	72.96	88.66	0.00	84.97	131.49
29	Le Grand-Saconnex	GE	80.44	72.96	88.66	0.00	84.97	131.49
30	Plan-les-Ouates	GE	80.44	72.96	88.66	0.00	84.97	131.49
31	Versoix	GE	80.44	72.96	88.66	0.00	84.97	131.49
32	Veyrier	GE	80.44	72.96	88.66	0.00	84.97	131.49
33	Brig-Glis	VS	80.58	70.41	91.74	112.85	54.77	45.68
34	Uzwil	SG	81.74	73.17	91.15	85.96	86.37	46.45
35	Ascona	TI	81.96	62.58	103.26	71.24	32.39	86.58
36	Bassersdorf	ZH	81.99	81.72	82.29	109.96	65.12	71.93
37	Sierre	VS	82.36	66.98	99.26	99.88	62.45	39.64
38	Nürensdorf	ZH	82.84	83.34	82.29	119.70	64.17	68.35
39	Visp	VS	82.91	71.09	95.88	125.78	40.00	50.98
40	Oberuzwil	SG	83.31	72.78	94.88	85.77	49.16	85.47
41	Chur	GR	83.61	67.67	101.11	100.11	40.49	65.14
42	Kaiseraugst	AG	83.74	75.50	92.80	111.01	80.97	34.84
43	Dietikon	ZH	83.82	85.22	82.29	108.14	73.39	75.49

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

	Municipality	Canton	API	API_{-e}	EL	WM	SW	WS
44	Suhr	AG	83.92	78.77	89.58	112.85	55.06	70.89
45	Buochs	NW	84.25	75.51	93.86	104.14	97.25	24.08
46	Martigny	VS	84.52	65.77	105.12	93.12	68.14	36.44
47	Rümlang	ZH	84.97	88.12	81.51	145.01	45.36	78.39
48	Schwyz	SZ	85.00	79.57	90.97	128.21	55.17	58.18
49	Küttigen	AG	85.08	79.34	91.38	60.15	88.66	88.11
50	Bussigny-près-Lausanne	VD	85.22	64.82	107.62	0.00	76.87	115.34
51	Kirchberg (SG)	SG	85.95	75.37	97.56	86.28	77.54	62.36
52	Sion	VS	85.95	79.66	92.86	145.40	50.58	46.56
53	Bellinzona	TI	85.97	66.91	106.90	93.44	41.66	68.10
54	Domat/Ems	GR	86.14	69.29	104.64	162.86	24.29	26.07
55	Crissier	VD	86.17	62.36	112.33	0.00	37.79	149.87
56	Buchs (AG)	AG	86.24	81.57	91.38	119.82	72.88	53.47
57	Zermatt	VS	86.36	81.00	92.25	90.79	77.71	74.94
58	Wünnewil-Flamatt	FR	86.58	67.32	107.74	120.94	81.09	0.00
59	Aarau	AG	86.77	82.58	91.38	107.14	63.21	79.36
60	Blonay	VD	87.10	63.63	112.89	41.22	27.10	124.86
61	Einsiedeln	SZ	87.14	91.55	82.29	99.24	74.04	102.86
62	Kreuzlingen	TG	87.19	87.44	86.91	109.56	75.60	78.50
63	Losone	TI	87.23	56.75	120.72	125.37	47.04	0.00
64	Neuenhof	AG	87.47	84.71	90.50	120.18	70.18	65.61
65	Kloten	ZH	87.56	93.67	80.84	96.27	73.42	112.92
66	Regensdorf	ZH	87.82	92.85	82.29	163.28	40.74	79.92
67	Freienbach	SZ	88.07	90.79	85.09	132.94	84.91	55.84
68	Giubiasco	TI	88.16	71.10	106.90	68.92	53.72	91.93
69	Wettingen	AG	88.19	90.09	86.10	116.15	80.58	74.79
70	Yverdon-les-Bains	VD	88.23	65.42	113.30	0.00	80.97	112.75
71	Wil (SG)	SG	88.33	89.48	87.07	86.28	98.31	83.14
72	Oberengstringen	ZH	88.35	93.87	82.29	119.44	70.18	94.32
73	Hergiswil (NW)	NW	88.48	83.58	93.86	126.49	70.58	55.55
74	Glarus	GL	88.65	87.16	90.28	111.30	81.84	69.25
75	Neuhausen am Rheinfall	SH	89.23	86.06	92.71	123.01	56.14	82.05
76	St. Margrethen	SG	89.28	81.80	97.50	79.14	91.82	73.62
77	Bad Ragaz	SG	90.08	89.11	91.15	106.29	53.91	110.17
78	Chiasso	TI	90.27	73.18	109.05	103.98	48.58	69.48
79	Wollerau	SZ	90.40	95.23	85.09	134.92	76.32	76.70
80	Epalinges	VD	90.48	65.21	118.23	0.00	45.88	149.87
81	Malters	LU	90.52	76.97	105.40	96.47	69.27	66.14
82	Rheinfelden	AG	90.67	88.73	92.80	111.01	102.71	51.87
83	Reinach (BL)	BL	90.71	79.60	102.91	89.14	81.51	68.20
84	Gossau (ZH)	ZH	90.71	98.04	82.66	92.32	113.97	86.51
85	Egg	ZH	90.72	98.39	82.29	117.67	64.78	115.65
86	Dietlikon	ZH	90.82	103.33	77.08	144.40	67.28	101.88
87	Bagnes	VS	91.04	87.29	95.16	75.01	138.84	43.88
88	Ecublens (VD)	VD	91.15	71.87	112.33	0.00	64.78	149.87
89	Widnau	SG	91.15	81.01	102.29	87.10	53.98	104.12
90	Sissach	BL	91.20	77.89	105.83	115.86	59.38	60.62
91	Willisau	LU	91.24	68.10	116.66	82.14	73.36	48.70
92	Seuzach	ZH	91.47	99.83	82.29	140.80	63.73	98.54
93	Renens (VD)	VD	91.72	72.96	112.33	0.00	64.78	153.22
94	Muttenz	BL	91.87	81.83	102.91	89.14	102.57	52.36
95	Embrach	ZH	92.02	100.87	82.29	135.57	70.18	99.91
96	Rapperswil-Jona	SG	92.24	87.30	97.66	127.28	75.25	61.12
97	Buchs (ZH)	ZH	92.31	101.42	82.29	156.86	73.30	77.38
98	Weinfelden	TG	92.42	88.41	96.84	107.82	64.78	94.81
99	Baden	AG	92.52	89.52	95.81	88.84	59.38	122.62
100	Meggen	LU	92.74	74.80	112.46	101.30	66.22	58.07
101	Wohlen (AG)	AG	92.75	89.41	96.43	102.05	72.88	94.80
102	Arth	SZ	92.76	89.38	96.47	124.69	71.69	73.83
103	Capriasca	TI	92.89	81.06	105.88	64.74	59.03	120.74
104	Schübelbach	SZ	92.93	83.40	103.40	129.63	59.88	63.44
105	Rolle	VD	93.30	75.46	112.89	0.00	133.65	86.78
106	Wetzikon (ZH)	ZH	93.39	104.65	81.03	101.46	127.94	82.72
107	Muri (AG)	AG	93.42	85.81	101.78	147.74	62.42	50.31
108	Locarno	TI	93.75	69.21	120.72	76.22	45.88	87.43
109	Wangen-Brüttisellen	ZH	93.77	101.38	85.40	142.07	75.04	89.87
110	Küssnacht (SZ)	SZ	93.78	79.42	109.55	127.03	46.07	68.67
111	Villmergen	AG	93.85	87.44	100.89	130.75	43.19	92.61

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

	Municipality	Canton	API	API$_{-e}$	EL	WM	SW	WS
112	Frutigen	BE	93.94	77.91	111.56	124.16	71.46	39.54
113	Schaffhausen	SH	93.99	87.63	100.97	110.69	72.33	81.50
114	Bonstetten	ZH	94.09	104.83	82.29	147.20	89.99	79.32
115	Reinach (AG)	AG	94.13	97.86	90.04	119.70	91.77	83.02
116	Ingenbohl	SZ	94.41	80.63	109.55	134.50	53.98	56.55
117	Gaiserwald	SG	94.42	92.86	96.14	95.76	46.36	140.02
118	Lausanne	VD	94.54	72.96	118.23	0.00	64.78	153.22
119	Gränichen	AG	94.80	94.82	94.78	143.65	58.18	86.41
120	Herzogenbuchsee	BE	94.85	81.75	109.24	80.96	91.77	71.74
121	Münchenstein	BL	95.55	88.86	102.91	93.62	93.12	79.62
122	Zell (ZH)	ZH	95.70	107.91	82.29	110.58	98.40	115.54
123	Niederhasli	ZH	95.76	108.02	82.29	134.36	89.41	102.25
124	Unterseen	BE	95.82	75.65	117.98	118.27	107.17	0.00
125	Steinhausen	ZG	95.93	96.20	95.62	126.18	79.69	84.60
126	Aigle	VD	95.96	80.56	112.89	121.29	53.98	69.25
127	Le Mont-sur-Lausanne	VD	96.04	75.84	118.23	0.00	72.95	153.22
128	Obersiggenthal	AG	96.07	97.71	94.26	124.47	43.19	130.16
129	Diepoldsau	SG	96.20	90.00	103.01	94.82	75.58	100.80
130	Bottmingen	BL	96.24	90.17	102.91	88.81	86.37	95.59
131	Colombier (NE)	NE	96.40	86.07	107.74	55.47	102.57	98.31
132	Montreux	VD	96.43	81.44	112.89	0.00	120.51	119.17
133	Vevey	VD	96.43	81.44	112.89	0.00	120.51	119.17
134	Fehraltorf	ZH	96.47	108.71	83.01	150.57	84.07	94.23
135	Orbe	VD	96.55	70.77	124.86	56.45	82.06	72.66
136	Lutry	VD	96.55	86.27	107.84	0.00	67.57	190.88
137	Davos	GR	96.69	83.90	110.74	97.66	83.62	70.72
138	Affoltern am Albis	ZH	96.69	109.80	82.29	126.50	95.30	109.03
139	Prilly	VD	96.81	77.31	118.23	46.64	37.79	149.87
140	Bubikon	ZH	96.86	114.75	77.21	133.08	134.96	75.06
141	Langnau am Albis	ZH	96.89	110.18	82.29	118.99	67.48	147.47
142	Oberglatt	ZH	96.97	107.74	85.14	140.91	80.97	104.05
143	Hinwil	ZH	96.98	110.36	82.29	109.14	134.96	85.09
144	Nyon	VD	97.41	82.41	113.88	59.29	107.96	77.57
145	Untersiggenthal	AG	97.43	100.98	93.53	139.29	74.98	91.42
146	Luzern	LU	97.48	89.35	106.41	106.50	64.78	99.00
147	Möhlin	AG	97.67	102.11	92.80	111.01	124.16	69.68
148	La Tour-de-Peilz	VD	97.98	84.40	112.89	0.00	132.66	115.15
149	Sargans	SG	98.01	104.25	91.15	123.20	102.33	87.76
150	Brugg	AG	98.08	100.26	95.68	137.61	80.97	84.43
151	Altendorf	SZ	98.14	89.13	108.04	147.22	64.18	59.06
152	Nendaz	VS	98.15	82.23	115.65	43.11	139.65	58.78
153	Littau	LU	98.40	91.11	106.41	125.17	75.58	74.47
154	Zürich	ZH	98.45	128.66	65.27	111.35	159.08	112.89
155	Oftringen	AG	98.48	95.82	101.39	113.97	102.75	70.58
156	Lachen	SZ	98.63	96.30	101.18	140.32	86.37	63.87
157	Laufen	BL	98.68	90.90	107.23	116.90	91.77	64.51
158	Allschwil	BL	98.96	95.36	102.91	102.52	78.27	106.72
159	Thalwil	ZH	99.11	114.43	82.29	101.62	125.42	115.15
160	Bulle	FR	99.39	98.02	100.89	142.26	71.77	82.92
161	Bischofszell	TG	99.40	91.74	107.81	85.96	116.43	70.86
162	Dornach	SO	99.61	96.61	102.91	132.75	79.57	79.54
163	Urdorf	ZH	99.78	115.70	82.29	113.42	116.06	117.54
164	Baar	ZG	99.80	100.68	98.83	126.66	63.96	114.74
165	Uetikon am See	ZH	99.92	112.24	86.39	122.66	53.98	164.71
166	Neftenbach	ZH	100.04	116.20	82.29	114.85	50.04	188.69
167	Küsnacht (ZH)	ZH	100.72	114.14	85.97	92.68	118.13	130.88
168	Aadorf	TG	100.84	109.82	90.97	112.98	111.60	104.82
169	Pully	VD	101.02	83.38	120.41	0.00	118.69	127.04
170	Uster	ZH	101.06	115.21	85.52	101.08	113.73	130.63
171	Appenzell	AI	101.12	103.30	98.73	103.89	121.33	83.34
172	Flawil	SG	101.21	105.59	96.39	85.96	122.91	106.20
173	Pfäffikon	ZH	101.38	116.40	84.88	92.06	161.95	91.26
174	Arlesheim	BL	101.46	100.15	102.91	100.42	97.17	103.09
175	Gossau (SG)	SG	101.56	108.02	94.47	86.28	114.47	122.36
176	Wädenswil	ZH	101.59	119.16	82.29	109.60	121.04	126.51
177	Winterthur	ZH	101.64	116.09	85.77	120.06	114.26	114.18
178	Richterswil	ZH	101.85	119.67	82.29	164.77	106.50	89.66
179	Zug	ZG	102.13	108.19	95.48	126.66	94.69	104.62

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

	Municipality	Canton	API	API_{-e}	EL	WM	SW	WS
180	Eschenbach (SG)	SG	102.53	95.26	110.52	115.42	101.24	69.08
181	Mels	SG	102.61	102.32	102.93	115.03	96.61	96.02
182	Dürnten	ZH	102.67	116.98	86.95	74.83	188.94	80.86
183	Pratteln	BL	102.77	101.56	104.10	111.01	108.04	85.33
184	Saint-Prex	VD	102.82	93.65	112.89	0.00	140.68	134.76
185	Dübendorf	ZH	102.86	114.95	89.58	134.76	105.70	105.50
186	Chavannes-près-Renens	VD	103.10	94.71	112.33	71.26	64.78	149.87
187	Aesch (BL)	BL	103.18	103.43	102.91	100.70	107.96	101.22
188	Morges	VD	103.25	94.48	112.89	0.00	160.99	115.46
189	Thal	SG	103.30	103.97	102.57	98.89	98.50	114.82
190	Kriens	LU	103.34	100.54	106.41	110.24	73.86	119.75
191	Wartau	SG	103.69	102.67	104.81	138.31	165.66	0.00
192	Emmen	LU	103.71	95.74	112.46	117.71	86.37	84.30
193	Rothrist	AG	103.90	103.14	104.75	105.82	113.14	89.75
194	Köniz	BE	104.02	97.16	111.56	111.25	77.48	104.55
195	Fribourg	FR	104.07	100.74	107.74	119.55	85.89	98.29
196	Sursee	LU	104.08	96.46	112.46	93.92	105.61	89.10
197	Opfikon	ZH	104.13	115.55	91.58	127.45	118.56	100.65
198	Hünenberg	ZG	104.15	107.58	100.38	126.66	82.60	115.77
199	Uetendorf	BE	104.22	97.54	111.56	113.69	83.04	97.32
200	Payerne	VD	104.23	101.04	107.74	109.49	105.63	87.83
201	Meilen	ZH	104.32	111.66	96.26	108.40	107.68	119.14
202	Aarburg	AG	104.39	110.44	97.73	90.24	161.95	74.82
203	Oberriet (SG)	SG	104.54	115.48	92.52	110.38	155.46	77.49
204	Herisau	AR	104.72	117.07	91.15	87.71	124.16	138.18
205	Belp	BE	104.87	98.91	111.42	130.55	76.52	92.01
206	Binningen	BL	105.23	107.33	102.91	98.06	97.22	127.30
207	Zumikon	ZH	105.32	126.29	82.29	98.76	145.47	132.64
208	Frauenfeld	TG	105.41	107.51	103.10	117.72	91.77	114.43
209	Burgdorf	BE	105.69	111.30	99.53	131.61	106.96	96.08
210	Wald (ZH)	ZH	105.85	121.82	88.31	92.47	140.35	130.63
211	Steffisburg	BE	105.86	99.77	112.54	121.49	97.17	81.31
212	Hombrechtikon	ZH	105.92	127.42	82.29	141.32	172.74	65.07
213	Igis	GR	105.96	78.94	135.63	145.18	40.49	55.44
214	Maur	ZH	106.06	127.71	82.29	90.48	140.06	150.87
215	Cham	ZG	106.12	115.81	95.48	126.18	106.41	115.77
216	Fällanden	ZH	106.14	120.73	90.12	126.64	113.56	122.66
217	Oberwil (BL)	BL	106.55	109.87	102.91	88.81	121.30	118.20
218	Heimberg	BE	106.67	102.22	111.56	121.75	98.38	87.22
219	Horgen	ZH	106.69	128.26	82.99	123.84	124.32	136.85
220	Altdorf (UR)	UR	106.74	98.59	115.70	103.98	127.40	62.33
221	Amriswil	TG	106.80	109.54	103.78	85.96	147.74	91.56
222	Marly	FR	106.84	106.02	107.74	178.30	80.97	62.18
223	Bülach	ZH	107.16	129.80	82.29	91.49	166.78	127.54
224	Kirchberg (BE)	BE	107.27	111.93	102.15	132.91	125.29	77.02
225	Biasca	TI	107.31	95.11	120.72	127.40	69.92	90.60
226	Buchrain	LU	107.39	102.79	112.46	124.41	113.31	70.28
227	Therwil	BL	107.47	111.61	102.91	111.01	118.76	104.52
228	Männedorf	ZH	107.67	130.18	82.94	92.94	133.23	163.37
229	Frenkendorf	BL	107.67	109.84	105.29	111.39	129.56	87.10
230	Langnau im Emmental	BE	107.72	104.23	111.56	95.22	122.88	92.97
231	Münsingen	BE	107.92	113.17	102.15	108.25	107.64	123.94
232	Villars-sur-Glâne	FR	108.11	108.45	107.74	123.99	121.55	79.13
233	Unterägeri	ZG	108.19	119.75	95.48	126.18	81.54	154.56
234	Düdingen	FR	108.30	108.81	107.74	125.98	129.56	69.68
235	Uznach	SG	108.42	112.81	103.61	106.55	135.48	94.56
236	Echallens	VD	108.45	104.41	112.89	87.66	118.27	105.91
237	Bolligen	BE	108.46	105.78	111.41	104.07	85.68	129.07
238	Kilchberg (ZH)	ZH	108.58	132.52	82.29	142.87	134.96	119.75
239	Nidau	BE	108.62	93.28	125.46	114.31	107.96	56.90
240	Kerns	OW	108.68	104.41	113.37	136.53	118.76	57.50
241	Thun	BE	108.77	104.71	113.22	127.94	90.04	97.73
242	Birsfelden	BL	108.79	114.14	102.91	119.88	113.54	109.17
243	Solothurn	SO	108.97	117.89	99.17	115.28	113.36	125.33
244	Sirnach	TG	109.09	115.28	102.29	118.87	94.80	133.79
245	Olten	SO	109.10	126.58	89.88	105.45	149.67	122.45
246	Rothenburg	LU	109.10	106.05	112.46	114.64	84.47	120.86
247	Birmensdorf (ZH)	ZH	109.21	133.73	82.29	124.13	109.65	169.02

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

	Municipality	Canton	API	API$_{-e}$	EL	WM	SW	WS
248	Zollikofen	BE	109.28	107.20	111.56	108.88	117.58	94.37
249	Derendingen	SO	109.45	108.71	110.26	101.96	134.96	87.10
250	Schwarzenburg	BE	109.81	108.22	111.56	115.23	115.43	93.60
251	Reiden	LU	109.96	107.68	112.46	101.23	138.06	81.32
252	Wittenbach	SG	110.08	120.81	98.29	95.14	171.67	91.24
253	Porrentruy	JU	110.31	109.17	111.56	138.97	24.29	171.29
254	Teufen (AR)	AR	110.32	127.77	91.15	130.55	107.96	146.34
255	Gelterkinden	BL	110.84	115.89	105.29	124.34	118.76	104.52
256	Walenstadt	SG	111.36	102.62	120.96	132.86	112.76	62.09
257	Rüschlikon	ZH	111.41	137.92	82.29	119.93	140.95	152.29
258	Menziken	AG	111.61	131.25	90.04	125.95	178.14	86.01
259	Altstätten	SG	112.01	115.91	107.74	88.38	181.13	72.71
260	Zuchwil	SO	112.17	110.08	114.47	120.16	150.50	56.73
261	Wattwil	SG	112.37	124.62	98.92	109.96	149.51	112.19
262	Urtenen-Schönbühl	BE	112.53	113.69	111.25	105.65	106.38	129.43
263	Ittigen	BE	112.64	113.62	111.56	111.33	121.28	107.63
264	Delémont	JU	112.73	110.83	114.82	141.77	59.38	135.87
265	Liestal	BL	112.82	119.67	105.29	122.39	113.36	123.79
266	Würenlos	AG	112.88	122.32	102.51	119.44	161.95	82.50
267	Adligenswil	LU	113.13	113.74	112.46	103.39	126.84	109.77
268	Balsthal	SO	113.31	107.15	120.09	117.01	82.60	123.90
269	Fully	VS	113.79	102.78	125.89	83.81	162.33	57.29
270	Hochdorf	LU	113.80	124.41	102.15	112.32	138.55	121.03
271	Romanshorn	TG	114.14	132.74	93.71	97.60	156.05	142.08
272	Illnau-Effretikon	ZH	114.32	143.48	82.29	123.50	188.94	114.16
273	Ebikon	LU	114.36	116.10	112.46	135.71	132.26	79.52
274	Riehen	BS	114.69	119.23	109.72	99.94	129.69	126.86
275	Val-de-Travers	NE	114.97	109.83	120.62	83.07	137.65	106.11
276	Adliswil	ZH	115.03	144.83	82.29	159.91	145.75	129.07
277	Oberägeri	ZG	115.04	132.84	95.48	126.18	142.77	128.68
278	Ruswil	LU	115.18	117.66	112.46	119.39	142.50	89.23
279	Rüti (ZH)	ZH	115.21	136.69	91.62	129.81	150.61	128.46
280	Lenzburg	AG	115.35	127.63	101.87	153.41	109.46	121.94
281	Peseux	NE	115.39	125.94	103.80	128.63	97.17	154.24
282	Horw	LU	115.63	118.52	112.46	106.17	97.50	153.22
283	Goldach	SG	115.75	135.42	94.14	111.31	105.27	191.45
284	Rorschacherberg	SG	115.99	119.76	111.85	113.50	115.01	131.00
285	Sumiswald	BE	116.05	126.38	104.70	125.75	158.83	92.09
286	Wohlen bei Bern	BE	116.07	120.17	111.56	129.29	119.18	112.32
287	Alpnach	OW	116.27	118.91	113.37	153.88	129.56	73.23
288	Zofingen	AG	116.28	122.23	109.73	131.68	97.17	139.93
289	Bern	BE	116.48	143.96	86.28	148.75	132.66	151.44
290	Spiez	BE	116.77	121.51	111.56	120.71	148.10	93.69
291	Windisch	AG	116.82	131.40	100.81	145.97	142.33	105.37
292	Lyss	BE	117.77	122.06	113.06	129.03	137.85	98.23
293	Ostermundigen	BE	117.97	123.81	111.56	105.50	149.14	114.48
294	Basel	BS	118.18	125.89	109.72	98.80	129.69	148.34
295	St. Gallen	SG	118.29	133.41	101.68	98.65	112.17	190.31
296	Erlenbach (ZH)	ZH	118.54	140.91	93.96	114.13	126.25	182.89
297	Sarnen	OW	118.58	123.32	113.37	143.52	114.29	113.27
298	Ollon	VD	118.67	122.07	114.94	0.00	195.71	162.40
299	Wallisellen	ZH	118.69	147.25	87.32	134.29	159.31	146.97
300	Grenchen	SO	118.88	123.43	113.89	106.16	113.36	151.18
301	Münchenbuchsee	BE	118.97	127.06	110.08	153.44	148.57	78.10
302	Biel/Bienne	BE	119.41	126.30	111.84	99.47	145.75	131.64
303	Rorschach	SG	119.61	134.62	103.12	101.35	115.93	187.30
304	Bellach	SO	119.99	125.01	114.47	137.99	94.47	145.16
305	Neuenkirch	LU	121.22	129.20	112.46	110.93	172.10	100.96
306	Langenthal	BE	121.24	136.17	104.82	105.09	175.53	124.28
307	Châtel-Saint-Denis	FR	121.29	133.62	107.74	129.24	165.47	103.66
308	Muri bei Bern	BE	122.11	131.70	111.56	127.22	165.32	99.92
309	Worb	BE	122.66	127.88	116.93	135.14	107.96	142.20
310	Grabs	SG	122.85	130.16	114.81	125.89	158.23	104.16
311	Neuchâtel	NE	122.96	124.64	121.13	103.84	113.36	157.13
312	Moutier	BE	123.22	128.42	117.51	109.62	121.64	154.12
313	Herrliberg	ZH	123.50	163.75	79.27	150.95	161.95	178.22
314	La Chaux-de-Fonds	NE	123.72	126.09	121.13	122.28	127.85	127.91
315	Stäfa	ZH	123.86	153.44	91.38	109.70	149.70	200.29

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

	Municipality	Canton	API	API_{-e}	EL	WM	SW	WS
316	Arbon	TG	124.57	147.36	99.54	113.89	198.15	125.50
317	Trimbach	SO	124.77	129.03	120.09	112.66	150.06	122.45
318	Saanen	BE	127.64	142.28	111.56	123.09	159.29	142.78
319	Buchs (SG)	SG	129.06	141.96	114.89	124.34	168.13	131.05
320	Interlaken	BE	129.48	139.94	117.98	129.71	186.96	99.39
321	Murten	FR	133.75	154.93	110.49	159.73	179.80	123.48
322	Bex	VD	134.31	151.94	114.94	154.72	191.12	107.06
323	Zollikon	ZH	136.59	169.79	100.11	125.39	212.96	166.84
324	Le Locle	NE	151.72	179.57	121.13	121.21	134.96	284.71

Sources: Own estimations, based on Price Control (2012) and Federal Electricity Comission (2012).

A.2.2 Tables and figures

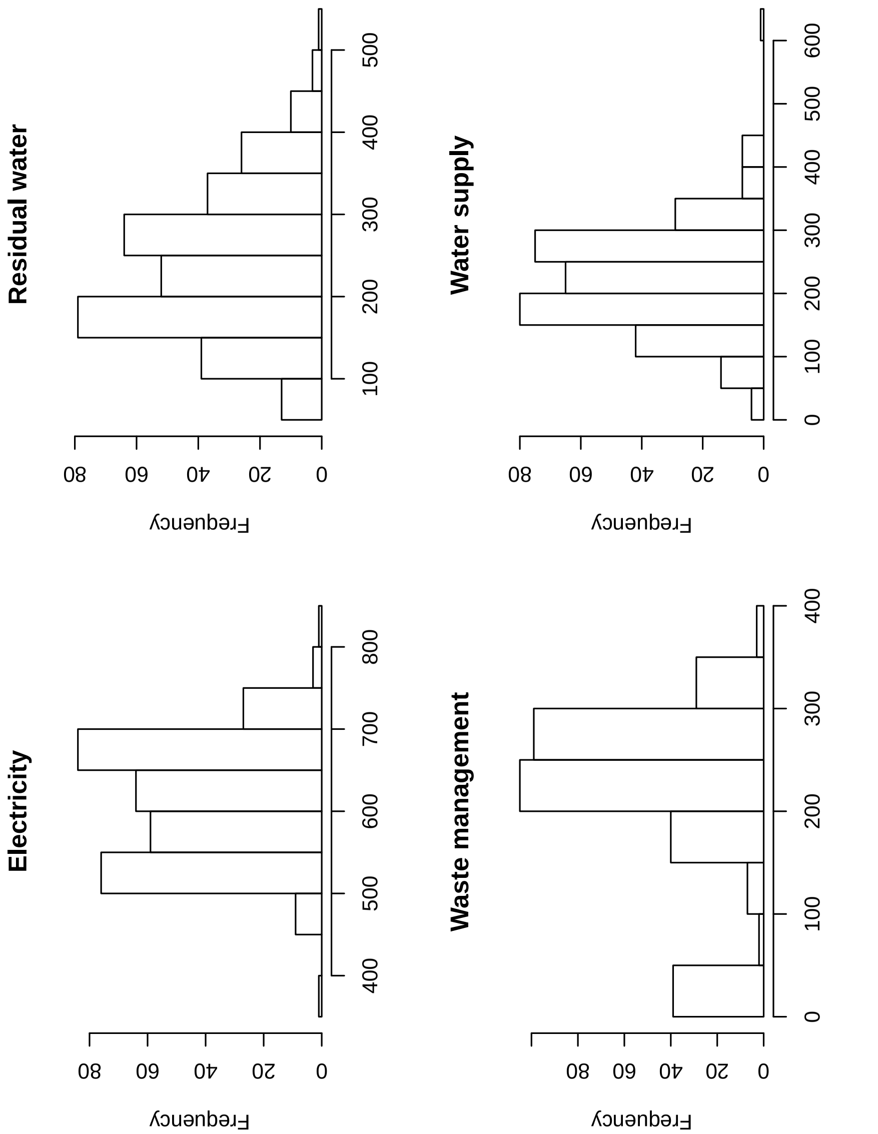


Figure A.1: Service price frequencies. The prices are scaled in Swiss francs (CHF). The distributions contain all 324 municipalities and the corresponding prices from 2012.

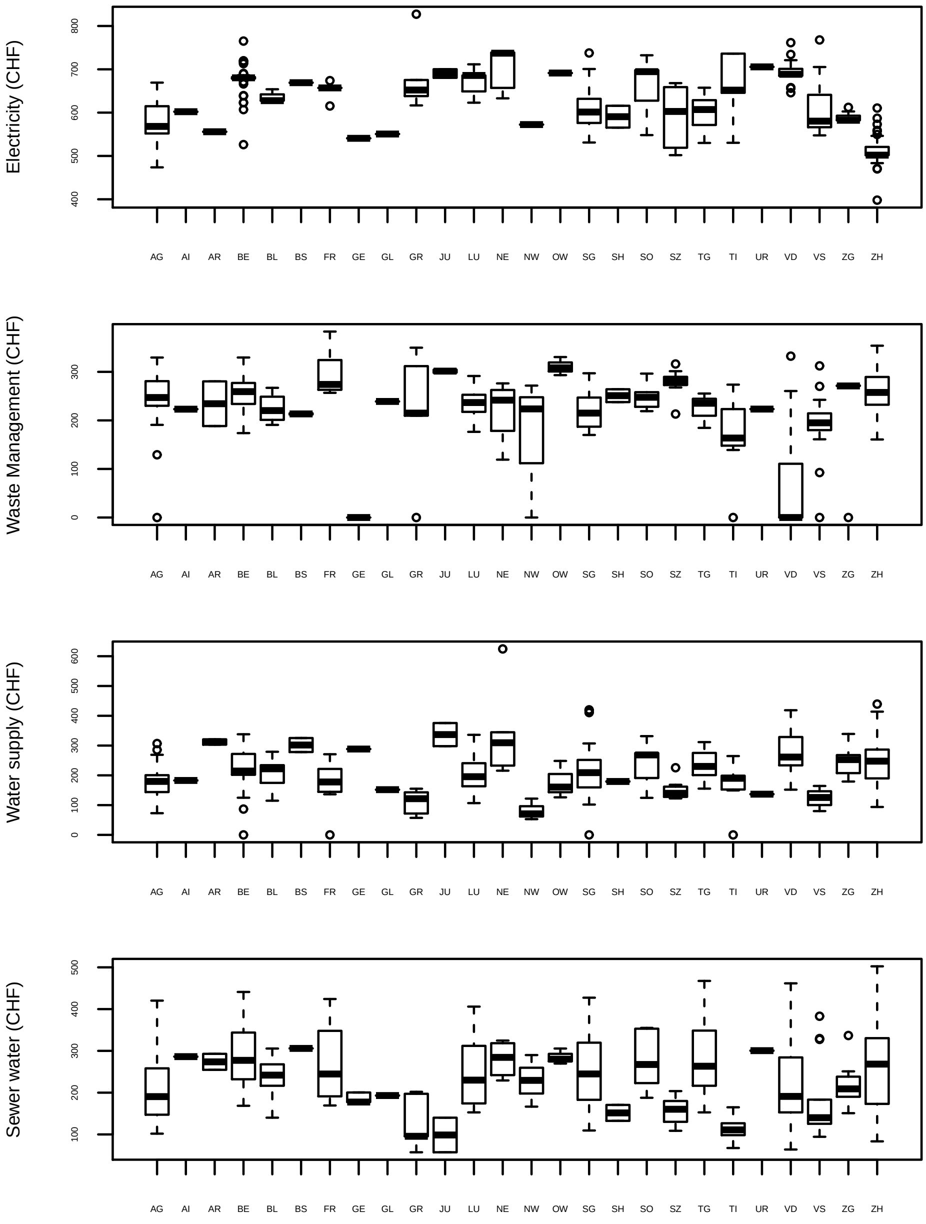


Figure A.2: Service price distribution within and across cantons. Distributions for every service and canton are plotted by box-plots. The bold bar indicates the median of every canton, the boxes the interquartile range, dashed lines the first and fourth quartile. Single points are outliers. Very small cantons, such as Glarus (GL) have only one municipality with 5'000 or more inhabitants, so only the median is plotted. In small cantons with only a few large municipalities, the box captures all observations. In Geneva (GE), all prices are administered at nearly identical levels and plotted in a box.

Table A.13: Economies of scale with modified specification

	(1) API	(2) API$_{-e}$	(3) API	(4) API$_{-e}$	(5) EL	(6) WM	(7) SW	(8) WS
Constant	4.678***	4.820***	4.598***	4.670***	4.520***	4.765***	4.890***	4.324***
	(0.058)	(0.101)	(0.055)	(0.077)	(0.049)	(0.079)	(0.129)	(0.144)
Population	0.000	0.000	0.000	0.000	−0.000	−0.000	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Agglomeration	−0.013	−0.092	0.020	−0.026	0.073**	−0.005	−0.163*	0.047
	(0.029)	(0.051)	(0.028)	(0.039)	(0.023)	(0.038)	(0.067)	(0.075)
Agglomeration^2	0.000	0.011*	−0.003	0.005	−0.012***	0.002	0.016*	0.001
	(0.003)	(0.005)	(0.003)	(0.004)	(0.002)	(0.004)	(0.007)	(0.008)
Suburban	−0.027	−0.067	−0.021	−0.060	0.016	−0.049	−0.007	−0.108
	(0.027)	(0.048)	(0.029)	(0.044)	(0.022)	(0.043)	(0.077)	(0.081)
High-income	0.036	0.040	0.059	0.066	0.021	−0.084	0.196	0.109
	(0.038)	(0.065)	(0.041)	(0.067)	(0.032)	(0.058)	(0.100)	(0.106)
Peri-urban	−0.049	−0.084	−0.054	−0.083	−0.021	−0.158*	−0.081	−0.071
	(0.037)	(0.070)	(0.039)	(0.059)	(0.034)	(0.080)	(0.121)	(0.100)
Tourist	−0.033	−0.123	−0.008	−0.057	0.046	−0.175	0.052	−0.116
	(0.069)	(0.135)	(0.063)	(0.091)	(0.037)	(0.108)	(0.158)	(0.178)
Industrial	0.003	−0.061	0.045	0.015	0.069*	0.006	−0.040	0.060
	(0.042)	(0.073)	(0.040)	(0.063)	(0.035)	(0.067)	(0.113)	(0.106)
Agronomic	−0.001	−0.138	0.032	−0.079	0.134**	−0.119	0.008	−0.185
	(0.081)	(0.161)	(0.072)	(0.145)	(0.041)	(0.096)	(0.245)	(0.181)
French	−0.071***	−0.210***	0.009	−0.065	0.068***	−0.173*	−0.151*	0.171**
	(0.021)	(0.036)	(0.029)	(0.050)	(0.016)	(0.073)	(0.059)	(0.052)
Italian	−0.158**	−0.410***	−0.115**	−0.323***	0.062	−0.235*	−0.723***	−0.027
	(0.054)	(0.097)	(0.038)	(0.062)	(0.034)	(0.097)	(0.109)	(0.088)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.087	0.207	0.036	0.110	0.323	0.122	0.138	0.108
Jarque-Bera	0.711	8.714*	2.015	2.477	6.380*	29.150***	13.722**	37.529***
F-Statistic	0.858	2.462	0.6814	2.549	31.368***	1.068	1.962	5.299**

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API$_{-e}$ (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table. The F-test is for the joint hypothesis that agglomeration and population size mutually do not show significant impact on the dependent variable.

Table A.14: Economies of scale dependent on topography

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	4.703***	4.829***	4.520***	4.492***	4.592***	5.162***	4.511***	3.711***
	(0.154)	(0.292)	(0.134)	(0.218)	(0.168)	(0.206)	(0.426)	(0.351)
log(Population)	−0.005	−0.021	0.017	0.018	0.011	−0.054*	0.026	0.086*
	(0.016)	(0.030)	(0.014)	(0.023)	(0.017)	(0.021)	(0.044)	(0.037)
Agglomeration	−0.012	0.005	−0.013	0.007	−0.036***	0.031**	−0.037	0.020
	(0.007)	(0.013)	(0.006)	(0.011)	(0.006)	(0.011)	(0.023)	(0.019)
Suburban	−0.017	−0.071	0.003	−0.039	0.051*	−0.065	0.004	−0.049
	(0.028)	(0.051)	(0.027)	(0.046)	(0.022)	(0.043)	(0.086)	(0.076)
High-income	0.053	0.058	0.095*	0.121	0.050	−0.097	0.251*	0.217*
	(0.043)	(0.079)	(0.039)	(0.070)	(0.035)	(0.059)	(0.118)	(0.105)
Peri-urban	−0.039	−0.101	−0.025	−0.077	0.027	−0.202*	−0.095	0.013
	(0.041)	(0.083)	(0.038)	(0.064)	(0.035)	(0.091)	(0.136)	(0.102)
Tourist	−0.016	−0.043	0.002	0.009	−0.004	−0.201	0.201	0.027
	(0.063)	(0.123)	(0.063)	(0.104)	(0.039)	(0.133)	(0.185)	(0.169)
Industrial	0.011	0.048	0.017	0.056	−0.035	0.044	0.099	0.035
	(0.031)	(0.056)	(0.032)	(0.054)	(0.028)	(0.051)	(0.114)	(0.082)
Agronomic	0.035	0.032	0.040	0.032	0.029	−0.097	0.274	−0.077
	(0.069)	(0.140)	(0.069)	(0.141)	(0.043)	(0.100)	(0.227)	(0.159)
Midland	0.001	−0.030	−0.000	−0.017	0.029	−0.053	−0.020	0.020
	(0.023)	(0.038)	(0.022)	(0.034)	(0.018)	(0.033)	(0.061)	(0.049)
Alps	0.118**	0.092	0.100*	0.062	0.147***	0.004	−0.116	0.228
	(0.040)	(0.070)	(0.040)	(0.067)	(0.019)	(0.049)	(0.182)	(0.133)
Jura	−0.036	−0.123*	−0.044	−0.123**	0.043*	−0.019	−0.243**	−0.180**
	(0.027)	(0.048)	(0.025)	(0.041)	(0.020)	(0.040)	(0.078)	(0.064)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.058	0.043	0.069	0.091	0.231	0.053	0.058	0.142
Jarque-Bera	0.175	12.119**	2.248	4.393	3.547	145.142***	9.803**	17.934***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.15: Economies of scale and regions

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	4.537***	4.337***	4.502***	4.366***	4.742***	5.118***	3.945***	3.742***
	(0.135)	(0.217)	(0.129)	(0.202)	(0.124)	(0.181)	(0.368)	(0.381)
log(Population)	−0.002	0.003	0.004	0.004	−0.009	−0.073***	0.055	0.074
	(0.014)	(0.023)	(0.014)	(0.021)	(0.013)	(0.019)	(0.039)	(0.039)
Agglomeration	−0.004	−0.002	0.001	0.007	−0.008	0.020	−0.031	0.043*
	(0.007)	(0.013)	(0.007)	(0.010)	(0.005)	(0.012)	(0.023)	(0.021)
Suburban	−0.028	−0.068	−0.023	−0.073	0.019	−0.112**	0.009	−0.048
	(0.027)	(0.045)	(0.026)	(0.040)	(0.018)	(0.040)	(0.080)	(0.083)
High-income	0.048	0.062	0.064	0.062	0.027	−0.174**	0.254*	0.203
	(0.038)	(0.062)	(0.039)	(0.061)	(0.029)	(0.056)	(0.106)	(0.108)
Peri-urban	−0.040	−0.094	−0.035	−0.086	0.017	−0.231**	−0.065	0.013
	(0.035)	(0.068)	(0.034)	(0.053)	(0.023)	(0.080)	(0.129)	(0.107)
Tourist	0.002	−0.020	0.003	−0.001	0.014	−0.153	0.195	−0.095
	(0.054)	(0.116)	(0.041)	(0.064)	(0.033)	(0.094)	(0.150)	(0.169)
Industrial	0.024	0.031	0.032	0.032	0.018	−0.007	0.122	0.078
	(0.032)	(0.055)	(0.034)	(0.056)	(0.022)	(0.059)	(0.114)	(0.092)
Agronomic	0.027	−0.019	0.029	−0.030	0.066	−0.173	0.209	−0.109
	(0.078)	(0.145)	(0.075)	(0.141)	(0.054)	(0.100)	(0.219)	(0.160)
Espace Midland	0.227***	0.397***	0.196***	0.348***	0.065***	0.328***	0.338***	0.081
	(0.022)	(0.038)	(0.034)	(0.055)	(0.019)	(0.086)	(0.072)	(0.071)
North-west	0.093***	0.249***	0.053	0.180**	−0.049*	0.262**	0.180*	−0.221**
	(0.025)	(0.038)	(0.037)	(0.057)	(0.021)	(0.089)	(0.075)	(0.069)
Zurich	0.121***	0.414***	0.067	0.326***	−0.195***	0.338***	0.319***	−0.029
	(0.023)	(0.035)	(0.037)	(0.058)	(0.020)	(0.093)	(0.077)	(0.065)
East	0.103***	0.248***	0.076*	0.208***	−0.040	0.208*	0.140	−0.041
	(0.028)	(0.052)	(0.037)	(0.061)	(0.021)	(0.086)	(0.091)	(0.085)
Central	0.104***	0.228***	0.081*	0.193**	−0.009	0.356***	0.088	−0.186*
	(0.028)	(0.047)	(0.038)	(0.059)	(0.022)	(0.085)	(0.077)	(0.084)
Ticino	−0.031	−0.139	−0.020	−0.106	0.050	0.031	−0.552***	−0.113
	(0.056)	(0.100)	(0.046)	(0.080)	(0.038)	(0.124)	(0.131)	(0.099)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.283	0.377	0.231	0.285	0.531	0.242	0.177	0.147
Jarque-Bera	1.315	46.140***	0.047	0.140	1.793	49.201***	34.055**	28.648***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.16: Tax rates and rents, controlled for scale effects

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.353***	6.015***	5.721***	4.660***	3.675***	6.075***	0.212	1.059
	(0.429)	(0.795)	(0.470)	(0.827)	(0.370)	(0.972)	(1.318)	(1.349)
log(Tax)	0.218***	0.233**	0.219***	0.265***	0.194***	−0.096	0.576***	0.334*
	(0.051)	(0.084)	(0.049)	(0.079)	(0.036)	(0.070)	(0.124)	(0.135)
log(Rent)	−0.054	−0.159	0.084	0.124	0.020	−0.081	0.305	0.263
	(0.060)	(0.127)	(0.070)	(0.128)	(0.046)	(0.168)	(0.198)	(0.209)
log(Population)	0.008	0.011	0.011	0.008	0.006	−0.061**	0.047	0.064
	(0.014)	(0.026)	(0.014)	(0.022)	(0.016)	(0.021)	(0.038)	(0.040)
Agglomeration	−0.006	0.022	−0.011	0.013	−0.038***	0.027*	−0.027	0.035
	(0.007)	(0.012)	(0.007)	(0.012)	(0.006)	(0.012)	(0.022)	(0.021)
Suburban	−0.002	−0.059	0.005	−0.057	0.068**	−0.101*	0.020	−0.046
	(0.027)	(0.048)	(0.027)	(0.044)	(0.022)	(0.043)	(0.078)	(0.082)
High-income	0.116**	0.138	0.107**	0.096	0.098**	−0.149*	0.269*	0.179
	(0.041)	(0.078)	(0.040)	(0.071)	(0.034)	(0.064)	(0.114)	(0.119)
Peri-urban	−0.035	−0.095	−0.031	−0.090	0.029	−0.230**	−0.070	−0.001
	(0.039)	(0.077)	(0.038)	(0.062)	(0.033)	(0.080)	(0.129)	(0.106)
Tourist	−0.001	−0.005	−0.031	−0.045	−0.007	−0.186	0.132	−0.114
	(0.051)	(0.097)	(0.052)	(0.078)	(0.039)	(0.117)	(0.168)	(0.172)
Industrial	0.014	0.063	0.008	0.040	−0.038	0.005	0.084	0.059
	(0.032)	(0.058)	(0.031)	(0.055)	(0.024)	(0.060)	(0.115)	(0.090)
Agronomic	−0.007	−0.038	−0.015	−0.067	0.015	−0.118	0.106	−0.194
	(0.074)	(0.151)	(0.068)	(0.142)	(0.036)	(0.091)	(0.249)	(0.166)
French	−0.082***	−0.213***	−0.028	−0.110*	0.054**	−0.159*	−0.248***	0.102
	(0.023)	(0.043)	(0.029)	(0.050)	(0.016)	(0.071)	(0.071)	(0.070)
Italian	−0.113*	−0.389***	−0.062	−0.284***	0.133***	−0.268**	−0.654***	0.043
	(0.053)	(0.097)	(0.034)	(0.065)	(0.032)	(0.099)	(0.119)	(0.087)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.220	0.260	0.126	0.148	0.348	0.139	0.180	0.131
Jarque-Bera	0.614	6.889*	0.604	1.507	4.708	27.655***	15.043***	27.272***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.17: Tax rates, rents and regions

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.349***	6.107***	6.032***	5.447***	3.536***	6.874***	1.374	0.950
	(0.449)	(0.903)	(0.430)	(0.718)	(0.301)	(0.948)	(1.320)	(1.547)
log(Tax)	0.170***	0.116	0.142**	0.109	0.217***	−0.275**	0.408**	0.248
	(0.051)	(0.088)	(0.047)	(0.080)	(0.032)	(0.087)	(0.140)	(0.151)
log(Rent)	−0.019	−0.082	0.087	0.082	0.016	−0.247	0.239	0.543*
	(0.060)	(0.137)	(0.060)	(0.101)	(0.043)	(0.142)	(0.172)	(0.230)
Suburban	−0.018	−0.056	−0.021	−0.063*	0.028	−0.030	−0.070	−0.058
	(0.017)	(0.030)	(0.017)	(0.028)	(0.014)	(0.029)	(0.052)	(0.057)
High-income	0.084**	0.108	0.066*	0.072	0.060*	−0.048	0.143	0.102
	(0.032)	(0.060)	(0.033)	(0.056)	(0.027)	(0.054)	(0.083)	(0.096)
Peri-urban	−0.037	−0.095	−0.038	−0.083	0.024	−0.123	−0.157	−0.037
	(0.027)	(0.055)	(0.026)	(0.043)	(0.018)	(0.066)	(0.106)	(0.077)
Tourist	0.018	−0.010	−0.007	−0.019	0.043	−0.096	0.175	−0.283
	(0.046)	(0.102)	(0.038)	(0.060)	(0.031)	(0.101)	(0.155)	(0.178)
Industrial	0.027	0.023	0.023	0.010	0.035	0.026	0.119	−0.089
	(0.028)	(0.050)	(0.029)	(0.052)	(0.018)	(0.054)	(0.102)	(0.081)
Agronomic	−0.004	−0.058	0.004	−0.061	0.045	−0.110	0.156	−0.252
	(0.084)	(0.149)	(0.078)	(0.144)	(0.052)	(0.088)	(0.243)	(0.143)
Espace Midland	0.185***	0.347***	0.179***	0.338***	0.024	0.348***	0.316***	0.146
	(0.028)	(0.057)	(0.034)	(0.057)	(0.019)	(0.080)	(0.081)	(0.097)
North-west	0.091**	0.232***	0.064	0.195***	−0.044*	0.248**	0.218**	−0.110
	(0.029)	(0.054)	(0.036)	(0.059)	(0.021)	(0.081)	(0.083)	(0.094)
Zurich	0.120***	0.408***	0.072*	0.341***	−0.197***	0.353***	0.317***	0.079
	(0.024)	(0.042)	(0.035)	(0.058)	(0.018)	(0.086)	(0.075)	(0.071)
East	0.105**	0.227**	0.095*	0.223***	−0.023	0.151	0.229*	0.069
	(0.035)	(0.075)	(0.039)	(0.064)	(0.024)	(0.079)	(0.101)	(0.128)
Central	0.152***	0.251***	0.119**	0.219***	0.059**	0.273**	0.242**	−0.108
	(0.031)	(0.056)	(0.039)	(0.065)	(0.022)	(0.083)	(0.088)	(0.104)
Ticino	0.003	−0.130	0.020	−0.072	0.103**	−0.034	−0.425**	0.034
	(0.058)	(0.105)	(0.050)	(0.086)	(0.039)	(0.125)	(0.149)	(0.121)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.324	0.389	0.255	0.288	0.594	0.247	0.189	0.147
Jarque-Bera	1.973	27.792***	0.184	0.025	10.660**	24.050***	30.316***	33.787***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.18: Tax rates and rents, robust for cantonal clusters

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.517***	5.493***	6.052***	4.266***	4.620	5.229***	1.000	0.317
	(0.754)	(1.245)	(0.687)	(1.238)	(0.889)	(1.449)	(1.657)	(2.131)
log(Tax)	0.211	0.277	0.202	0.296	0.127	−0.069	0.542*	0.424
	(0.112)	(0.149)	(0.112)	(0.155)	(0.110)	(0.095)	(0.220)	(0.268)
log(Rent)	−0.069	−0.046	0.044	0.208	−0.139	−0.033	0.245	0.504*
	(0.074)	(0.164)	(0.056)	(0.158)	(0.108)	(0.234)	(0.182)	(0.246)
Suburban	−0.017	−0.033	−0.021	−0.041	0.003	−0.011	−0.062	−0.041
	(0.021)	(0.033)	(0.020)	(0.032)	(0.020)	(0.034)	(0.053)	(0.072)
High-income	0.097***	0.156***	0.077**	0.104*	0.036	−0.033	0.170*	0.149*
	(0.028)	(0.052)	(0.030)	(0.050)	(0.025)	(0.053)	(0.078)	(0.074)
Peri-urban	−0.052*	−0.079	−0.059**	−0.082*	−0.028	−0.122*	−0.162	−0.031
	(0.023)	(0.049)	(0.021)	(0.041)	(0.023)	(0.050)	(0.089)	(0.053)
Tourist	0.001	−0.064	−0.023	−0.082	0.064	−0.171	0.131	−0.265
	(0.044)	(0.101)	(0.046)	(0.068)	(0.044)	(0.121)	(0.154)	(0.147)
Industrial	0.019	0.001	0.021	0.003	0.042*	0.004	0.099	−0.085
	(0.039)	(0.064)	(0.037)	(0.065)	(0.019)	(0.043)	(0.105)	(0.102)
Agronomic	−0.002	−0.098	−0.003	−0.104	0.092***	−0.117*	0.120	−0.334***
	(0.065)	(0.123)	(0.057)	(0.109)	(0.035)	(0.052)	(0.222)	(0.069)
French	−0.078*	−0.232***	−0.023	−0.120	0.084***	−0.169	−0.230***	0.066
	(0.036)	(0.066)	(0.043)	(0.065)	(0.058)	(0.099)	(0.063)	(0.120)
Italian	−0.115***	−0.383***	−0.068*	−0.279***	0.122***	−0.253***	−0.664***	0.062
	(0.031)	(0.046)	(0.031)	(0.045)	(0.030)	(0.034)	(0.066)	(0.093)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.223	0.254	0.125	0.148	0.253	0.118	0.180	0.115

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. The standard errors are in parentheses below every estimate and corrected for heteroscedasticity with cluster variable 'canton'. The number of observations (N) and adjusted R-squared are reported in the second part of the table.

Table A.19: Single institutions

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	5.989***	5.017***	6.347***	5.599***	3.711***	5.126***	2.177***	3.772***
	(0.223)	(0.353)	(0.202)	(0.278)	(0.186)	(0.196)	(0.424)	(0.487)
Parliament	0.017	0.013	0.023	0.025	0.019	−0.014	−0.006	0.128*
	(0.018)	(0.035)	(0.018)	(0.029)	(0.016)	(0.031)	(0.058)	(0.059)
Accounts audit	0.047*	0.094**	0.032	0.062	−0.001	0.035	0.204*	0.017
	(0.021)	(0.036)	(0.021)	(0.034)	(0.018)	(0.036)	(0.079)	(0.070)
Business audit	−0.013	−0.078*	−0.013	−0.076*	0.063***	−0.090**	0.029	−0.159**
	(0.018)	(0.030)	(0.019)	(0.030)	(0.015)	(0.032)	(0.067)	(0.058)
External audit	−0.062	−0.113	−0.135**	−0.194*	−0.023	−0.130	−0.138	−0.176
	(0.038)	(0.070)	(0.047)	(0.079)	(0.023)	(0.086)	(0.137)	(0.140)
Finance commission	−0.004	0.028	0.086	0.121	−0.008	0.165	0.201*	−0.096
	(0.038)	(0.068)	(0.048)	(0.081)	(0.024)	(0.091)	(0.095)	(0.133)
log(Tax)	0.254***	0.330***	0.177***	0.206***	0.186***	−0.078	0.497***	0.164
	(0.046)	(0.073)	(0.042)	(0.058)	(0.039)	(0.041)	(0.089)	(0.101)
Suburban	−0.026	−0.047	−0.021	−0.035	−0.003	−0.027	−0.064	0.022
	(0.019)	(0.031)	(0.018)	(0.030)	(0.016)	(0.033)	(0.053)	(0.059)
High-income	0.062*	0.106*	0.071*	0.122*	0.003	−0.078	0.194*	0.290***
	(0.030)	(0.051)	(0.032)	(0.056)	(0.027)	(0.046)	(0.078)	(0.083)
Peri-urban	−0.048	−0.075	−0.040	−0.050	−0.026	−0.131	−0.160	0.080
	(0.031)	(0.055)	(0.029)	(0.045)	(0.028)	(0.074)	(0.111)	(0.084)
Tourist	0.005	−0.021	0.012	−0.001	0.026	−0.108	0.195	−0.147
	(0.046)	(0.097)	(0.041)	(0.057)	(0.034)	(0.101)	(0.141)	(0.165)
Industrial	0.025	0.011	0.027	0.009	0.044*	0.014	0.099	−0.051
	(0.031)	(0.056)	(0.031)	(0.055)	(0.021)	(0.058)	(0.106)	(0.075)
Agronomic	−0.021	−0.146	−0.005	−0.127	0.109***	−0.124	0.051	−0.359*
	(0.079)	(0.167)	(0.075)	(0.156)	(0.031)	(0.096)	(0.261)	(0.157)
French	−0.018	−0.083	0.070*	0.047	0.050*	−0.047	−0.013	0.297**
	(0.032)	(0.053)	(0.035)	(0.056)	(0.020)	(0.074)	(0.109)	(0.091)
Italian	−0.031	−0.173	0.060	−0.053	0.094*	−0.031	−0.427*	0.183
	(0.064)	(0.112)	(0.054)	(0.094)	(0.042)	(0.129)	(0.173)	(0.143)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.282	0.337	0.206	0.245	0.277	0.198	0.202	0.157
Jarque-Bera	1.635	9.695**	0.042	0.103	2.379	26.481***	14.854***	32.843***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.20: Institutional control in regions

	(1) API	(2) API$_{-e}$	(3) API	(4) API$_{-e}$	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.195***	5.530***	6.556***	5.951***	3.615***	5.368***	3.011***	4.491***
	(0.214)	(0.392)	(0.200)	(0.335)	(0.130)	(0.305)	(0.488)	(0.614)
Parliament	0.022	0.028	0.026	0.032	0.012	−0.022	−0.002	0.165**
	(0.017)	(0.032)	(0.016)	(0.028)	(0.011)	(0.030)	(0.059)	(0.059)
FinCom	−0.002	−0.010	0.001	−0.006	0.008	−0.011	0.010	0.012
	(0.010)	(0.017)	(0.010)	(0.016)	(0.007)	(0.015)	(0.032)	(0.031)
log(Tax)	0.180***	0.155	0.107**	0.075	0.211***	−0.182**	0.293**	−0.011
	(0.046)	(0.086)	(0.042)	(0.070)	(0.028)	(0.063)	(0.105)	(0.132)
Suburban	−0.013	−0.051	−0.011	−0.049	0.030*	−0.044	−0.060	0.005
	(0.017)	(0.029)	(0.018)	(0.028)	(0.014)	(0.033)	(0.055)	(0.061)
High-income	0.087**	0.100*	0.095**	0.104*	0.067**	−0.109*	0.197*	0.282**
	(0.029)	(0.045)	(0.032)	(0.052)	(0.023)	(0.051)	(0.079)	(0.086)
Peri-urban	−0.025	−0.080	−0.022	−0.062	0.031	−0.141	−0.157	0.059
	(0.028)	(0.054)	(0.028)	(0.045)	(0.018)	(0.073)	(0.117)	(0.088)
Tourist	0.023	−0.009	0.010	−0.002	0.049	−0.124	0.192	−0.199
	(0.050)	(0.114)	(0.038)	(0.061)	(0.030)	(0.096)	(0.146)	(0.172)
Industrial	0.035	0.034	0.033	0.022	0.040*	0.021	0.117	−0.029
	(0.029)	(0.052)	(0.030)	(0.054)	(0.018)	(0.057)	(0.111)	(0.078)
Agronomic	0.005	−0.047	0.011	−0.053	0.051	−0.111	0.148	−0.208
	(0.084)	(0.152)	(0.078)	(0.143)	(0.051)	(0.089)	(0.238)	(0.172)
Espace Midland	0.193***	0.358***	0.183***	0.336***	0.034	0.339***	0.286**	0.115
	(0.027)	(0.051)	(0.034)	(0.055)	(0.019)	(0.084)	(0.091)	(0.096)
North-west	0.107***	0.269***	0.071	0.209***	−0.044*	0.253**	0.162*	−0.141
	(0.025)	(0.043)	(0.037)	(0.059)	(0.019)	(0.088)	(0.081)	(0.077)
Zurich	0.136***	0.436***	0.091*	0.366***	−0.192***	0.325***	0.290***	0.128
	(0.023)	(0.043)	(0.035)	(0.058)	(0.018)	(0.086)	(0.081)	(0.077)
East	0.124***	0.273***	0.094*	0.231***	−0.023	0.182*	0.151	0.002
	(0.027)	(0.054)	(0.037)	(0.062)	(0.020)	(0.087)	(0.096)	(0.098)
Central	0.173***	0.288***	0.131***	0.234***	0.068***	0.266**	0.186*	−0.110
	(0.028)	(0.049)	(0.038)	(0.063)	(0.020)	(0.086)	(0.086)	(0.103)
Ticino	0.009	−0.095	0.000	−0.082	0.088*	0.017	−0.510***	−0.162
	(0.054)	(0.097)	(0.049)	(0.086)	(0.038)	(0.131)	(0.134)	(0.099)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.326	0.388	0.253	0.289	0.595	0.232	0.181	0.136
Jarque-Bera	2.042	40.442***	0.018	0.119	10.699**	31.357***	35.772***	39.747***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API$_{-e}$ (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.21: Institutional control and topography

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.974***	6.802***	6.176***	4.658***	4.156***	5.119***	1.897	1.618
	(0.354)	(0.681)	(0.382)	(0.712)	(0.337)	(1.045)	(1.118)	(1.001)
Parliament	−0.026	−0.112***	0.001	−0.047	0.061***	−0.076*	−0.168**	0.085
	(0.017)	(0.031)	(0.017)	(0.029)	(0.013)	(0.034)	(0.056)	(0.049)
FinCom	−0.030***	−0.043**	−0.028***	−0.035**	−0.019**	−0.044***	−0.044	−0.018
	(0.008)	(0.014)	(0.008)	(0.013)	(0.006)	(0.012)	(0.025)	(0.022)
log(Tax)	0.146**	0.140	0.156***	0.210**	0.141***	−0.110	0.481***	0.247*
	(0.047)	(0.084)	(0.043)	(0.069)	(0.040)	(0.081)	(0.125)	(0.111)
log(Rent)	−0.096*	−0.169	0.071	0.232*	−0.062	0.057	0.151	0.408**
	(0.045)	(0.092)	(0.054)	(0.106)	(0.043)	(0.155)	(0.147)	(0.152)
Suburban	−0.007	−0.037	−0.010	−0.042	0.029	0.001	−0.084	−0.055
	(0.020)	(0.037)	(0.020)	(0.032)	(0.018)	(0.031)	(0.061)	(0.057)
High-income	0.104**	0.159*	0.079*	0.089	0.048	−0.046	0.152	0.153
	(0.034)	(0.065)	(0.032)	(0.060)	(0.033)	(0.058)	(0.094)	(0.095)
Peri-urban	−0.045	−0.113	−0.042	−0.099	0.021	−0.129	−0.248*	0.000
	(0.034)	(0.069)	(0.032)	(0.053)	(0.027)	(0.083)	(0.117)	(0.081)
Tourist	0.004	−0.023	−0.020	−0.060	0.029	−0.207	0.168	−0.132
	(0.049)	(0.097)	(0.049)	(0.086)	(0.032)	(0.129)	(0.170)	(0.178)
Industrial	0.023	−0.006	0.029	0.007	0.057*	0.001	0.073	−0.049
	(0.030)	(0.056)	(0.031)	(0.056)	(0.024)	(0.057)	(0.109)	(0.075)
Agronomic	−0.007	−0.076	0.002	−0.064	0.062	−0.145	0.137	−0.186
	(0.067)	(0.139)	(0.064)	(0.135)	(0.038)	(0.092)	(0.235)	(0.158)
Midland	0.002	−0.028	−0.002	−0.028	0.033	−0.051	−0.038	−0.005
	(0.020)	(0.036)	(0.021)	(0.033)	(0.018)	(0.036)	(0.062)	(0.047)
Alps	0.082*	0.036	0.094*	0.067	0.131***	0.045	−0.150	0.220
	(0.037)	(0.070)	(0.038)	(0.070)	(0.024)	(0.055)	(0.187)	(0.128)
Jura	−0.012	−0.133**	−0.010	−0.111**	0.108***	−0.046	−0.186*	−0.176**
	(0.024)	(0.044)	(0.024)	(0.040)	(0.019)	(0.043)	(0.073)	(0.062)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.210	0.167	0.170	0.146	0.312	0.082	0.128	0.170
Jarque-Bera	1.510	4.402	0.696	1.669	3.8692	102.861***	9.862**	24.742***

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table.

Table A.22: Institutional control, robust for cantonal clusters

	(1) API	(2) API_{-e}	(3) API	(4) API_{-e}	(5) EL	(6) WM	(7) SW	(8) WS
Constant	6.214***	5.342***	6.499***	5.735***	3.857***	5.239***	2.714***	3.833***
	(0.451)	(0.591)	(0.404)	(0.577)	(0.378)	(0.241)	(0.790)	(0.956)
Parliament	0.012	0.021	0.019	0.032	0.001	−0.009	0.013	0.135
	(0.024)	(0.044)	(0.021)	(0.033)	(0.017)	(0.032)	(0.734)	(0.083)
FinCom	−0.024	−0.024	−0.024	−0.024	−0.026	−0.034	−0.012	−0.015
	(0.013)	(0.017)	(0.013)	(0.015)	(0.020)	(0.020)	(0.030)	(0.036)
log(Tax)	0.216*	0.270*	0.153	0.183	0.166*	−0.092	0.410*	0.140
	(0.095)	(0.124)	(0.084)	(0.120)	(0.080)	(0.049)	(0.165)	(0.198)
Suburban	−0.014	−0.026	−0.006	−0.011	−0.002	−0.006	−0.033	0.036
	(0.024)	(0.040)	(0.026)	(0.042)	(0.027)	(0.039)	(0.058)	(0.085)
High-income	0.083*	0.152*	0.100*	0.178*	−0.002	−0.041	0.249*	0.340**
	(0.042)	(0.075)	(0.040)	(0.077)	(0.032)	(0.040)	(0.111)	(0.122)
Peri-urban	−0.042	−0.063	−0.036	−0.040	−0.028	−0.115	−0.136	0.076
	(0.030)	(0.054)	(0.032)	(0.055)	(0.030)	(0.067)	(0.097)	(0.079)
Tourist	−0.007	−0.068	−0.019	−0.061	0.047	−0.184	0.154	−0.195
	(0.047)	(0.110)	(0.044)	(0.067)	(0.033)	(0.117)	(0.147)	(0.135)
Industrial	0.028	0.013	0.029	0.011	0.048*	0.006	0.100	−0.042
	(0.040)	(0.067)	(0.041)	(0.061)	(0.020)	(0.045)	(0.106)	(0.107)
Agronomic	−0.007	−0.099	−0.006	−0.105	0.084*	−0.136*	0.111	−0.298***
	(0.073)	(0.136)	(0.063)	(0.116)	(0.038)	(0.053)	(0.233)	(0.075)
French	−0.094*	−0.250***	−0.033	−0.136	0.064	−0.164	−0.196*	0.066
	(0.038)	(0.063)	(0.049)	(0.074)	(0.053)	(0.089)	(0.085)	(0.139)
Italian	−0.087***	−0.364***	−0.056**	−0.292***	0.166*	−0.201***	−0.678***	−0.062
	(0.026)	(0.060)	(0.019)	(0.040)	(0.047)	(0.037)	(0.093)	(0.088)
N	324	324	281	281	324	285	324	320
adj. R-squared	0.240	0.260	0.157	0.145	0.256	0.134	0.170	0.093

Note: The estimations are on the logarithm of different dependent variables, as indicated in the header: API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply). All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. The standard errors are in parentheses below every estimate and corrected for heteroscedasticity with cluster variable 'canton'. The number of observations (N) and adjusted R-squared are reported in the second part of the table.

Table A.23: Capitalisation with different construction indicators

	(1) Rent	(2) Rent	(3) Rent	(4) Rent	(5) Rent	(6) Rent	(7) Rent	(8) Rent
Constant	4.770***	4.987***	4.786***	4.953***	5.738***	4.952***	4.999***	4.883***
	(0.334)	(0.322)	(0.281)	(0.276)	(0.402)	(0.366)	(0.262)	(0.266)
log(Tax)	−0.337***	−0.356***	−0.341***	−0.361***	−0.303***	−0.325***	−0.333***	−0.336***
	(0.040)	(0.041)	(0.040)	(0.040)	(0.038)	(0.037)	(0.040)	(0.038)
log(Population)	0.095***	0.090***	0.092***	0.087***	0.088***	0.095***	0.094***	0.090***
	(0.017)	(0.018)	(0.017)	(0.017)	(0.016)	(0.017)	(0.017)	(0.018)
Suburban	0.142***	0.139***	0.139***	0.136***	0.132***	0.142***	0.140***	0.141***
	(0.020)	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)	(0.020)	(0.021)
High-income	0.361***	0.352***	0.351***	0.342***	0.356***	0.367***	0.361***	0.352***
	(0.051)	(0.051)	(0.050)	(0.050)	(0.049)	(0.051)	(0.051)	(0.050)
Peri-urban	0.176***	0.174***	0.175***	0.173***	0.160***	0.175***	0.173***	0.169***
	(0.035)	(0.034)	(0.036)	(0.035)	(0.038)	(0.035)	(0.037)	(0.036)
Tourist	0.157***	0.162***	0.159***	0.165***	0.157**	0.159***	0.154**	0.161***
	(0.045)	(0.044)	(0.046)	(0.045)	(0.049)	(0.047)	(0.047)	(0.045)
Industrial	0.052	0.054	0.050	0.052	0.052	0.054	0.051	0.053
	(0.030)	(0.031)	(0.031)	(0.031)	(0.030)	(0.030)	(0.030)	(0.031)
Agronomic	0.069*	0.076**	0.077*	0.084**	0.083**	0.071*	0.066*	0.084**
	(0.033)	(0.029)	(0.030)	(0.026)	(0.031)	(0.034)	(0.033)	(0.029)
BA	0.650		0.668		0.584	0.632	0.640	0.649
	(0.811)		(0.797)		(0.811)	(0.817)	(0.816)	(0.804)
CF	1.593*		1.499*		1.095	1.481*	1.507*	1.729*
	(0.744)		(0.722)		(0.753)	(0.755)	(0.746)	(0.729)
log(API)	0.065	0.053						
	(0.063)	(0.063)						
log(API_{-e})			0.071	0.071				
			(0.042)	(0.043)				
log(EL)					−0.163*			
					(0.073)			
log(WM)						0.013		
						(0.058)		
log(SW)							0.014	
							(0.023)	
log(WS)								0.049*
								(0.022)
N	271	271	271	271	271	271	271	271
adj. R-squared	0.557	0.551	0.561	0.557	0.565	0.555	0.556	0.564
Jarque-Bera	11.510**	11.161**	15.043***	14.721***	17.265**	13.690**	12.874**	7.645*

Note: The dependent variable is the logarithm of 'Rent'. All price indexes, namely API (administered price index), API_{-e} (API without electricity), EL (electricity), WM (waste management), SW (sewer water) and WS (water supply) are used as explanatory variables. All coefficients are estimated by OLS, and significances are indicated as follows: 0 '***' 0.001 '**' 0.01 '*' 0.05. Heteroscedasticity consistent standard errors (hc3) are reported in parentheses below every estimate. The number of observations (N), adjusted R-squared and Jarque-Bera tests with null hypothesis 'normal residual distribution' are in the second part of the table. Building applications 'BA' and 'Constructions finished' (CF) replace 'Constructions ongoing'.

Table A.24: Capitalisation in regions

	(1) Rent	(2) Rent	(3) Rent	(4) Rent	(5) Rent	(6) Rent	(7) Rent	(8) Rent
Constant	6.213***	5.348***	6.277***	5.576***	5.734***	6.009***	6.064***	5.924***
	(0.517)	(0.331)	(0.490)	(0.284)	(0.448)	(0.371)	(0.350)	(0.392)
log(Tax)	−0.449***	−0.368***	−0.447***	−0.361***	−0.476***	−0.369***	−0.461***	−0.457***
	(0.060)	(0.044)	(0.060)	(0.044)	(0.072)	(0.044)	(0.065)	(0.066)
log(Population)	0.063***	0.051**	0.063***	0.052**	0.063***	0.046**	0.062***	0.058***
	(0.018)	(0.016)	(0.018)	(0.016)	(0.018)	(0.017)	(0.018)	(0.017)
Suburban	0.117***	0.091***	0.116***	0.091***	0.116***	0.088***	0.118***	0.113***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.021)	(0.021)	(0.021)
High-income	0.320***	0.276***	0.323***	0.281***	0.313***	0.276***	0.313***	0.298***
	(0.040)	(0.041)	(0.040)	(0.041)	(0.041)	(0.040)	(0.040)	(0.038)
Peri-urban	0.106**	0.106**	0.103**	0.106**	0.105**	0.092**	0.109***	0.101**
	(0.034)	(0.034)	(0.034)	(0.034)	(0.033)	(0.031)	(0.033)	(0.032)
Tourist	0.154	0.137*	0.154	0.137*	0.150	0.125*	0.149	0.163
	(0.095)	(0.060)	(0.093)	(0.060)	(0.092)	(0.059)	(0.095)	(0.096)
Industrial	0.076*	0.045	0.076*	0.047	0.072*	0.045	0.071*	0.075*
	(0.032)	(0.027)	(0.032)	(0.027)	(0.032)	(0.027)	(0.031)	(0.033)
Agronomic	0.036	0.016	0.034	0.017	0.032	0.007	0.032	0.046
	(0.059)	(0.033)	(0.057)	(0.033)	(0.063)	(0.035)	(0.063)	(0.055)
Constructions	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Espace Midland	−0.158***	−0.049	−0.148**	−0.042	−0.165***	−0.013	−0.169***	−0.169***
	(0.040)	(0.045)	(0.046)	(0.045)	(0.033)	(0.037)	(0.035)	(0.033)
North-west	−0.195***	−0.040	−0.186***	−0.039	−0.192***	−0.022	−0.201***	−0.184***
	(0.031)	(0.044)	(0.035)	(0.044)	(0.031)	(0.037)	(0.030)	(0.028)
Zurich	−0.106***	0.054	−0.091*	0.052	−0.088*	0.078*	−0.115***	−0.109***
	(0.032)	(0.046)	(0.042)	(0.047)	(0.039)	(0.038)	(0.030)	(0.028)
East	−0.277***	−0.148***	−0.269***	−0.146***	−0.277***	−0.131***	−0.284***	−0.276***
	(0.039)	(0.042)	(0.044)	(0.042)	(0.036)	(0.036)	(0.035)	(0.034)
Central	−0.220***	−0.050	−0.212***	−0.046	−0.229***	−0.026	−0.228***	−0.212***
	(0.036)	(0.043)	(0.037)	(0.043)	(0.036)	(0.037)	(0.035)	(0.035)
Ticino	−0.272***	−0.124	−0.277***	−0.121	−0.283***	−0.106	−0.261***	−0.282***
	(0.065)	(0.082)	(0.066)	(0.082)	(0.066)	(0.076)	(0.066)	(0.069)
log(API)	−0.024	0.079						
	(0.080)	(0.055)						
log(API_{-e})			−0.043	0.021				
			(0.064)	(0.034)				
log(EL)					0.107			
					(0.104)			
log(WM)						−0.055		
						(0.047)		
log(SW)							0.023	
							(0.020)	
log(WS)								0.058*
								(0.028)
N	324	281	324	281	324	285	324	320
adj. R-squared	0.667	0.690	0.669	0.688	0.669	0.689	0.669	0.676
Jarque-Bera	93.185***	49.277**	70.566***	50.7811***	86.375***	33.942***	102.834***	163.977***

Note: See table A.23.

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