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Limitations and impact of hedonic adjustment for the rent index

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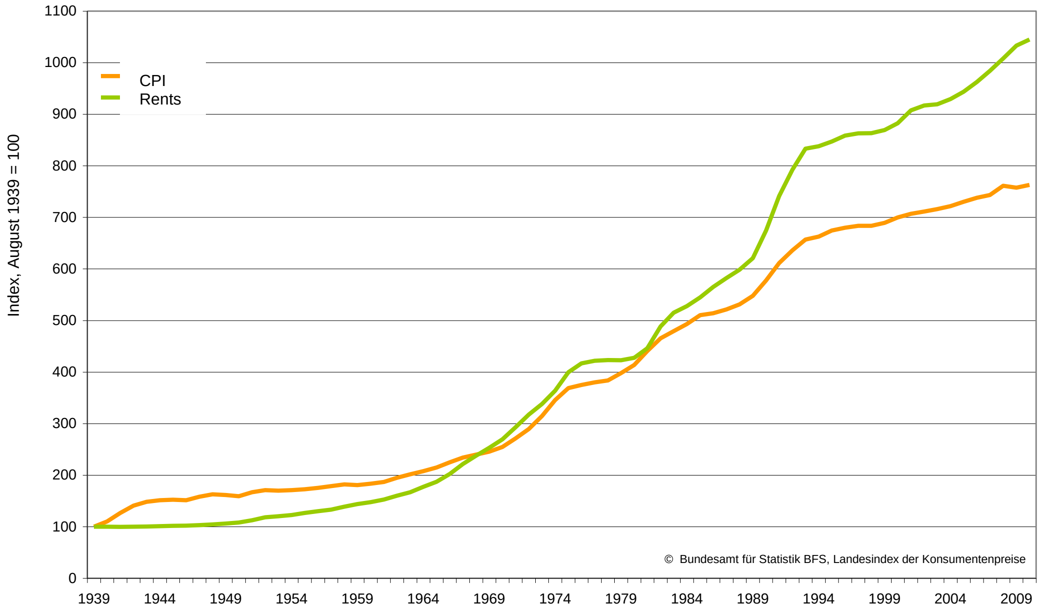
1 Introduction

Rents for housing[1] have been measured by the consumer price index (CPI) almost since its inception in 1922. They are a primary component of the standard basket of goods and services, accounting for 20% thereof. This proportion has remained remarkably stable for almost a century. But although the proportion of expenditure on rents has remained stable, this does not mean that rents for housing purposes have remained at the same price over the years. In 1924, a 4-room apartment in Zurich cost an average of CHF 70. In 2012, the equivalent sum was upwards of CHF 1,500. The increase in rents has therefore been considerable, much more so than the overall increase in prices (see Graph 1 below).

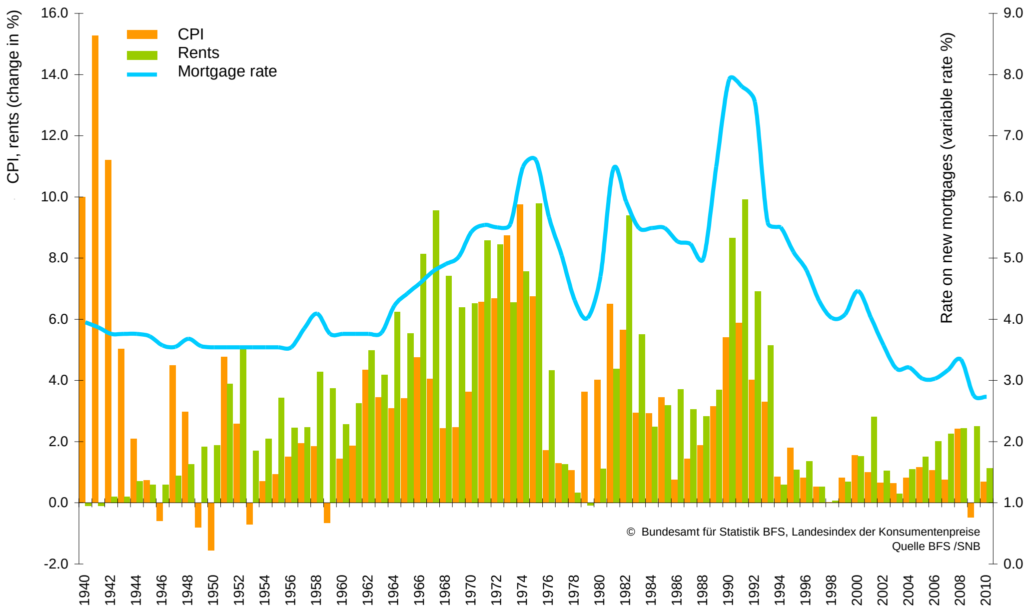
Graph 1: Consumer price index and rent index from 1939 to 2010



Graph 2 shows, the rise in rents was particularly high in 1967, 1975, 1982 and 1991 when the rate came to almost 10% in one year, driven by increases in mortgage rates.

1 In our definition, rent is net rent (excluding service charges) paid by the tenant for occupation of the dwelling. Vacant dwellings are not included in our sample.

Graph 2: Annual change in rents, CPI and mortgage rates



The rise in mortgage rates is not the only reason behind the increase in rents. The scarcity of land released for development and the excess of demand over supply in some parts of Switzerland have continued to push up rents. Statistically speaking, not only are rents a substantial spending item in Switzerland but they are trending in a significant manner. Furthermore, the housing market does not work in the same way as markets for other products contained in the standard basket of goods and services. Each dwelling is "unique", on account of its size, age and location. The rental stock is in a permanent state of flux as new dwellings are built, others are renovated and others deteriorate. Consequently, this statistic has always been especially worthy of consideration — a situation that has persisted since almost the beginning of the last century. Here is a brief historical overview.

Questions on rents have been included in population censuses carried out every 10 years. In 1923, the decision was made to carry out a periodic survey on rents for housing. Twenty-eight communes were instructed to conduct the survey and 10% of 2- to 4-room dwellings were included in it. From the early 1930s, data on rents were gathered every year. A distinction was already made between existing dwellings and new ones, so that the influence of the latter on rental trends could be determined. In 1977, the representativeness of the sample was improved, by covering rural communes and including dwellings with 1 to 5 rooms. As of 1977, the rents statistic has covered 100,000 dwellings in 85 communes and is conducted twice a year. The rent index underwent its greatest transformation in 1993. The basic principles determined back then, though since updated and refined, are still valid. They are explained in Section 2.1 as well as in Appendix 7.1.

One topic has always been centre stage: the neutralisation of quality effects over time. Depending on the quality-adjustment method used, we may be tempted to speculate on the potential underestimating, or overestimating, of the rent index and its impact on the overall rate of inflation. Number of rooms and dwelling age have always been considered as the main qualitative variables, which is why, since 1993, dwellings were post-stratified using them. From 1993 to 2005, further quality adjustments were conducted on rental properties in accordance with the renovation work carried out. Depending on whether renovation was full or partial, the dwelling was attributed points, thereby lowering its age artificially. Thus, by means of renovation work, it was possible for a dwelling built more than 20 years ago to be assigned to the 11-20 year cell. This procedure was halted in early 2006. It turned out that the link between renovations and rent levels was not so clear cut, with an in-house study demonstrating that renovated dwellings might be cheaper to rent than non-renovated accommodation in the same size category. It seems that renovation work is not so much designed to modernise dwellings as to keep them in good enough condition so they can continue to be rented out. Furthermore, this method was unable to silence criticism about the fact that we were comparing essentially non-comparable objects.

Between 2006 and 2010, no quality-adjustment methods were used. Dwellings were input into cells, depending on age and number of rooms without any further adjustment taking place. This gave rise to questions from users of the data such as whether a dwelling with a view over Lake Zurich could be compared with another situated in the midst of the Jurassian forests. Variables such as accessibility, regional fiscal capacity and exposure to noise are also likely to influence rents. These questions prompted us to develop a hedonic model, which was introduced in 2011 and which adjusts the quality of dwellings by their own characteristics (surface area, number of rooms, age, number of bathrooms and so forth), macro location (distance to town centre, stores in the neighbourhood, tax burden, etc.) and micro location (view, clearance, sunshine exposure, etc.).

After three years of using this model, we have taken steps to assess it and analyse the impact of quality adjustments on results. This paper aims to determine whether the impact is significant and, if so, which variables exert the greatest influence.

2 Rent index (RI) and hedonic adjustment

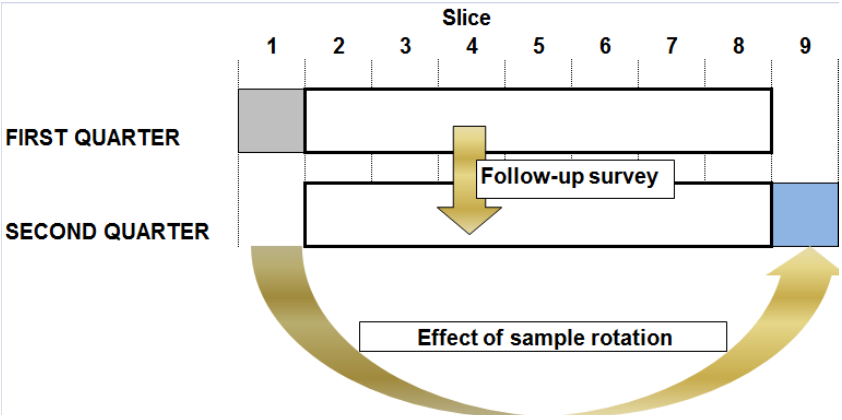
2.1 Constructing the rent index

The rent index measures mean changes in rents for apartments rented for the purpose of long-term residence in Switzerland. It is based on a rotating panel of approximately 10,000 dwellings, of which 1/8 is replenished quarterly using a stratified random sample. Four strata are pre-determined on the basis of building age for selecting the new sample. To construct the index[2], a further post-stratification stage is applied. This combines the building's age with extra details based on information gathered through surveys and the number of rooms. A matrix of 24 cells is thus determined, combining 6 categories for number of rooms (1-6 rooms) and 4 for building age (0-5 years, 6-10 years, 11-20 years and over 20 years)[3]. The recorded rents are assigned to a specific cell; within each one, two sub-indices are calculated: one for the panel segment (segment B), i.e. observations in both the current and previous period, and one for the rotating segment (segment AC), i.e. incoming (segment C) and outgoing (segment A). These sub-indices are defined as the relationship between the average rents of the two periods, with each calculated using a geometrical mean wherein each rent is weighted using its respective survey weight. The two sub-indices are then combined arithmetically on the basis of the number of observations in each segment to determine the cell's overall index. Lastly, each cell is given a weighting according to share of household expenditure in terms of housing. The total index is then obtained by arithmetically combining the 24 cells using their respective weightings.

Adjusting for quality essentially becomes problematic in terms of sample rotation, namely the comparison of apartments exiting the sample (A) with those joining it (C).

[2] This calculation is detailed in Appendix 7.1.
[3] No regional stratification is applied to rents.

Figure 1: Rent index sample rotation



For this segment, applying post-stratification based on building age and number of rooms cannot factor in all the variables likely to influence price. As such, the characteristics of dwellings leaving and joining a cell might be markedly different, e.g. in terms of surface area, location or view. Hedonic adjustment has primarily been developed for this segment, to which the adjustment is restricted in practice.

No adjustment is made to the panel segment (follow-up survey), and the quality of dwellings contained therein is deemed to be constant during the two years that they remain in the panel for several reasons. First, the gradual ageing of these dwellings cannot be considered as depreciative over such a short time span (otherwise, stable rents would have been regularly adjusted and reinterpreted as price increases). Next, the link between renovation and quality enhancement has been discredited, as noted in Section 1. Lastly, modifications to certain characteristics (e.g. surface area) over the two-year monitoring period are classified as corrections for reading errors that cannot be identified in the survey. Applying an adjustment here would result in fictive swings in rents resulting from these corrections.

2.2 Hedonic adjustment

2.2.1 Principles

The method used for the RI is "hedonic repricing" (or hedonic quality adjustment), which is often used in the production of official statistics. In particular, it is recommended for the harmonised consumer price index (HCPI)[4].

Fundamentally, this relies on the estimation of an explicit quality-adjustment factor, which is then applied to the recorded price change. In the first instance, a hedonic regression must be estimated, thus forging a link between the prices of different varieties of a given product and the quantities of their primary characteristics. This determines an implicit price for each feature. Next, theoretical prices can be estimated for new and substituted products by applying regression coefficients to the values ascribed to these characteristics. The adjustment factor is then calculated using the relationship between the mean theoretical price of incoming products and that of outgoing products. While the version used by Eurostat (2011) is basically adhered to, for a Jevons-type index, hedonic repricing involves estimating two indices:

- an unadjusted price index calculated using a standard procedure: $I_t^{unadj} = \frac{\prod_{i=1}^{nt}(P_{i,t})^{\frac{1}{nt}}}{\prod_{i=1}^{n0}(P_{i,0})^{\frac{1}{n0}}}$;

[4] See especially Destatis (2009).

- an adjustment factor (quality index[5]) calculated on the basis of estimated coefficients within the hedonic regression ($\widehat{\beta_{ref}}$, estimate period *ref* is not constrained) and characteristics observed in regard to the products (x_i):

$$I_t^{quality} = \frac{\prod_{i=1}^{nt}\left(x_{i,t}\widehat{\beta_{ref}}\right)^{\frac{1}{nt}}}{\prod_{i=1}^{n0}\left(x_{i,0}\widehat{\beta_{ref}}\right)^{\frac{1}{n0}}}$$

The quality-adjusted price index is then obtained by: $I_t^{adj} = I_t^{unadj} \cdot \frac{1}{I_t^{quality}}$

The advantages of hedonic repricing are mainly practical in nature and make it easier to use the method in the regular production of statistics. Most notably, this approach does not require a new estimate of hedonic regression for each period, and also allows for this to be estimated on the basis of different source data — possibly even a pooling of data serving as a calculation basis for the index. Estimated regression can therefore be underpinned by a wider range of data, which then improves the quality of the estimated regression coefficients that will be used for adjustment purposes. However, scope for retaining constant regression coefficients must also take into account the characteristics of the market that is being covered, because this is based on the implicit assumption of stable prices between different characteristics. In property, especially in the rental market, the slow rate of change in production techniques and consumer tastes means that we can harness this possibility with a reasonable degree of certainty. This is because, over the medium term, the features of new housing remain close to those of existing dwellings, so there is no incidence on prices of characteristics[6].

2.2.2 Application to the Swiss rent index

The estimation of hedonic regression linking rent with the main characteristics thereof is the basis for all hedonic adjustment. As enabled by the hedonic repricing approach, this regression could be estimated using a more exhaustive set of data than that used for drawing up the quarterly index. First, the rent structure survey in 2003[7] covering approximately 100,000 dwellings was used and that made it possible to establish a link between rents and different structural characteristics. Next, various supplementary sources of information were employed to provide fuller details about the different factors relating to a dwelling's location[8]. Altogether, some 90,000 observations were used for estimating the hedonic regression, the main indicators of which are shown in Appendix 7.2[9].

For dwelling i, the chosen relation is of log-linear type:

$$\ln(y_i) = \propto + \beta_1 X_{1,i} + \beta_2 \ln(X_{2,i}) + \varepsilon_i$$

The logarithm of an estimated rent is then calculated using the formula

$$\ln(\hat{y}_i) = \widehat{\propto} + \widehat{\beta_1} X_{1,i} + \widehat{\beta_2} \ln(X_{2,i}) \quad (1)$$

[5] Triplett (2006) talks about a "quantity index of characteristics".
[6] The example of regional characteristics, the prices of which may fluctuate more over time, may be considered an exception. This will be discussed in more detail in the section dealing with the adjustment breakdown.
[7] The last rent structure survey dates back to 2003. The main variable of the survey is net rent, which is analysed from the angle of several factors such as the dwelling's location, its specific characteristics and rental conditions, which are also measured. Since 2010, the survey has been replaced by the structural survey as part of the new census system (see Note 11), which has the same objectives in its "living conditions" component.
[8] These external data are either supplied by the Federal Office for the Environment (exposure to noise), the Federal Finance Administration (fiscal capacity) and the Federal Office for Spatial Development (travelling times), or purchased from Ernst Basler + Partner AG (other microfactors) and Braingroup AG (tax burden).
[9] The task of estimating the hedonic regression was entrusted to an outside service provider, the Zurich Cantonal Bank (Financial Engineering, Real Estate).

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Hedonic regression thus combines both unadjusted explanatory variables (X_1, most notably different dummy variables) and logged variables (X_2). Furthermore, this corresponds to a multiplicative relation whereby rent *y* is explained by constant α to which different factors are applied, with each relating to a particular characteristic:

$$\hat{y}_i = e^{\hat{\alpha}} \cdot e^{\widehat{\beta_1} X_{1,i}} \cdot X_{2,i}{}^{\widehat{\beta_2}} = \tilde{\alpha} \cdot e^{\widehat{\beta_1} X_{1,i}} \cdot X_{2,i}{}^{\widehat{\beta_2}} \qquad (1')$$

Overall, 58 variables have been integrated into the model,[10] 12 of which relate to the structural characteristics of a dwelling and 46 to its location. Moreover, 47 variables are dummy variables, 39 of which concern location. Characteristics associated with location concern both micro factors (e.g. exposure to noise, lake views and distance to lakes) and macro factors (e.g. fiscal capacity, tax rate and canton). As is standard for this type of analysis, structural characteristics include dwelling size, number of rooms (in the form of a dummy variables) and building age.

While the quarterly rent survey yields values for the entirety of structural variables input into the model, variables relating to location and stemming from outside sources for practical reasons cannot be measured or matched each quarter. The chosen solution is to estimate, on the basis of hedonic regression, a specific location value for each inhabited hectare in Switzerland. Rental estimates for a given dwelling thus rely on the addition of two components: a structural component estimated by applying regression coefficients to the measured values for the variables concerned, and a value reflecting the location of the dwelling, which is tied to the hectare on which it is situated. If the different variables are grouped by type, equation (1) can be transcribed differently to isolate two distinct, additive segments (see below: *j* structural variables and *k* variables relating to location):

$$\ln(\hat{y}_i) = \hat{\alpha} + \underbrace{\sum_{j=1}^{12} \hat{\beta}_j X_{j,i}^{structure}}_{Structural\ component} + \underbrace{\sum_{k=1}^{47} \widehat{\beta_k} X_{k,i}^{location}}_{Locational\ component}$$

$$= \hat{\alpha} + \underbrace{\sum_{j=1}^{12} \hat{\beta}_j X_{j,i}^{structure}}_{Structural\ component} + \widehat{Hectare\_value}_{\,i}$$

Lastly, in keeping with the hedonic repricing approach, an adjustment factor can be calculated on the basis of estimated rents for incoming and outgoing dwellings. For cell i, the index relating to the rotating segment is obtained as follows (here k and j designate dwellings):

$$I_{AC,i}^{t} = \frac{\left(\prod_{j=1}^{n_{C,i}^{t}} y_{j,t}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{t-1}} y_{k,t-1}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}} \cdot \hat{g}_{C,i}^{t}} = \frac{\left(\prod_{j=1}^{n_{C,i}^{t}} y_{j,t}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{t-1}} y_{k,t-1}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}}} \cdot \frac{1}{\hat{g}_{C,i}^{t}}$$

With an adjustment factor, which is estimated using the following ratio between geometrical means:

$$\hat{g}_{C,i}^{t} = \frac{\left(\prod_{j=1}^{n_{C,i}^{*t}} \hat{y}_{j,t,2003}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{*t-1}} \hat{y}_{k,t-1,2003}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}}}$$

Two key factors should be emphasised at this point. First, the geometrical mean used for calculating the adjustment factor is a weighted average that takes into account the estimated survey weight for each observation. These weights are determined on the basis of inclusion probability and include an adjustment for non-response within the different strata. The combined weight is calibrated to the

[10] A full list of variables can be consulted in Appendix 7.2.

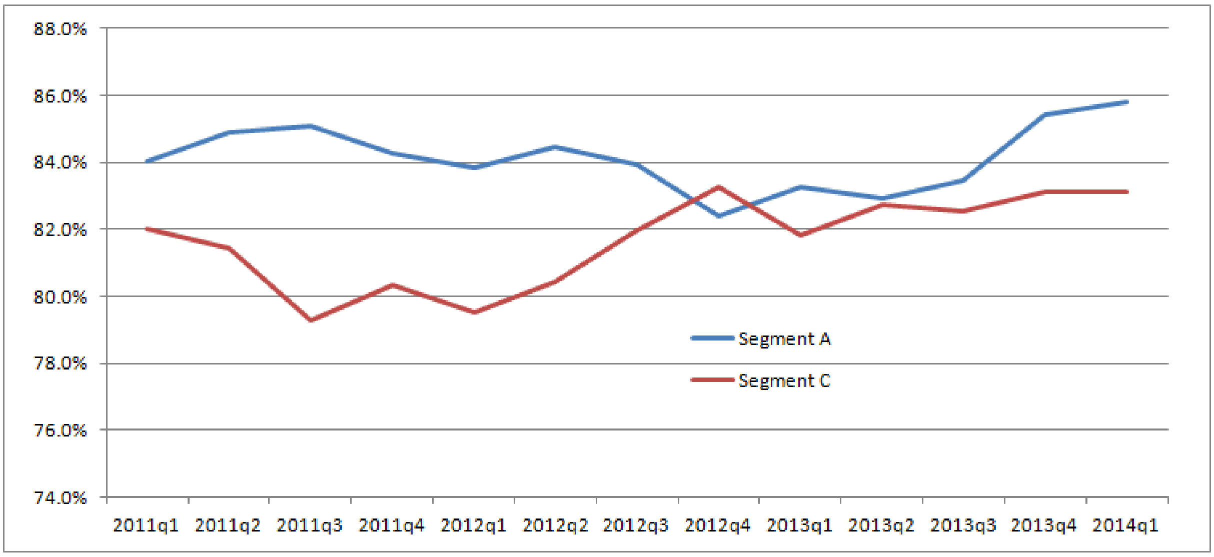
regional breakdown of housing observed within the structural survey[11] to limit fluctuations in the regional representation arising from the sample[12].
Next, the number of dwellings used for estimating the factor is lower than that of dwellings affected by rotation (n > n*). This is because dwellings, concerning which the information required for estimating a rent is not fully available, are not included in the factor's calculation[13]. Two reasons account for the lack of these data:

- The absence of a link to precise geographical coordinates. The precise localisation of a dwelling (or, specifically, the building in which it is situated) is made possible by matching it with the federal register of buildings and dwellings, which lists all residential buildings and their constituent dwellings in Switzerland. Since this matching process is conducted on the basis of a dwelling's address as opposed to a more specific identifier, around 12% of data is screened out.

- Absence of data on apartment surface area. No imputation is carried out in the event of there being no data on apartment surface area[14]. In some cases, however, matching with the federal register of buildings and dwellings can yield this information. In the end, data are still lacking on some 6% of dwellings, which accounts for their being excluded from the adjustment.

As indicated in Graph 3, the relationship between values n* and n is shown to be stable, and no marked divergence is observable between the two segments concerned (incoming and outgoing). The relationship is generally more favourable for outgoing units (segment A), as missing data may have been filled in while the dwelling was present in the panel. The low ebb observed for incoming units (segment C) up to and including the 2nd quarter of 2012 was due to increased complications in gathering data on surface area. A substantial improvement can be observed from the 3rd quarter of 2012.

Graph 3: Proportion of observations entering the adjustment-factor calculation

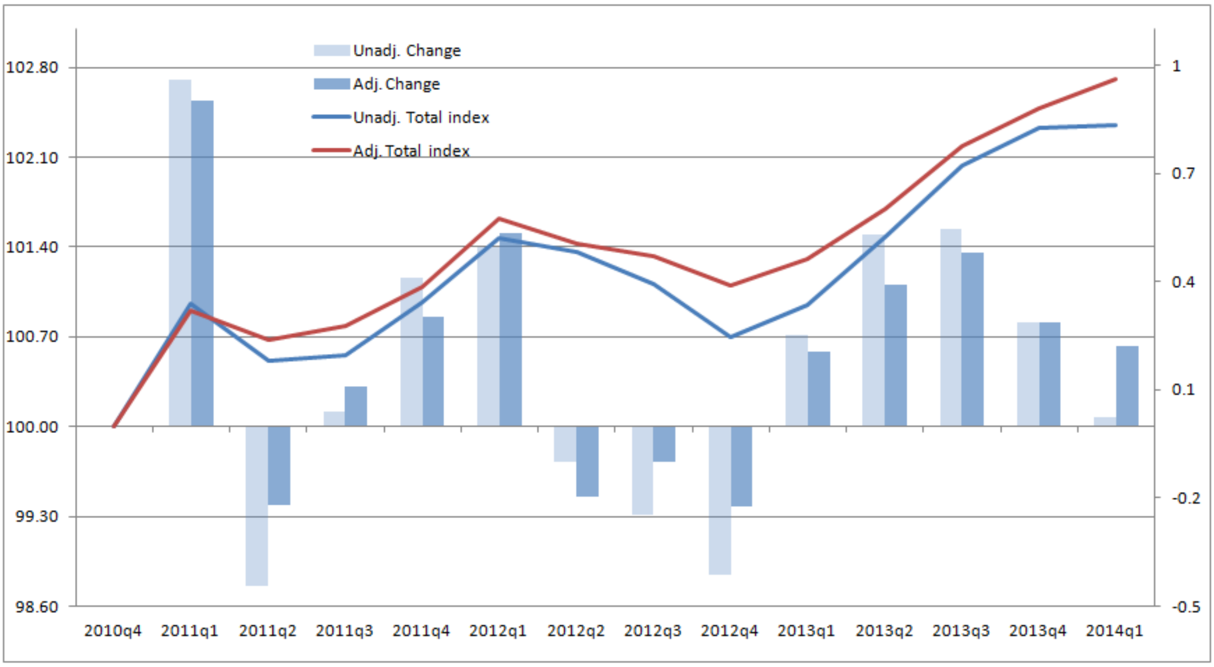


[11] The structural survey is an annual survey of approximately 200,000 individuals; from 2010, this has replaced the long-standing federal population census.
[12] We should bear in mind that stratification does not take into account the regional dimension of rents.
[13] Screening out observations is preferred to the partial inclusion of characteristics or inclusion on the basis of imputed values. As stated by Triplett (2006), partial inclusion of characteristics may be problematic in the event of multicollinearity.
[14] For other variables, imputation is carried out: the building's age (vital for assigning a dwelling to a specific cell) and storey.

3 Impact of adjustment

Since its introduction, the impact of hedonic adjustment on the rent-index data series has at times been marked on a quarterly basis, but has remained limited if the index's overall trend (or mean change) is observed[15].

Graph 4: Unadjusted and adjusted rent index (left-hand scale) and change (right-hand scale)



As such, while the mean quarterly change in rents is close to +0.2% after adjustment, some quarters experience a sharp change to their trend. For example, the change concerning the 1st quarter of 2014 rose 10-fold from a modest +0.02% to +0.22%. Less striking was the change affecting the 3rd quarter of 2011, which increased 3-fold; in contrast, the decline affecting the 2nd quarter of 2011 was halved by the adjustment. Generally speaking, adjusting leads to deviations relative to unadjusted change (between -0.14% and +0.22%[16]), which are distributed more or less evenly between positive and negative values. With the exception of four quarters (Q3 2011, Q1 2012, Q2 2012 and Q1 2014), the adjustment flattened the unadjusted quarterly change. However, the adjustment was not strong enough in any period to change a positive trend to a negative trend, or vice versa.

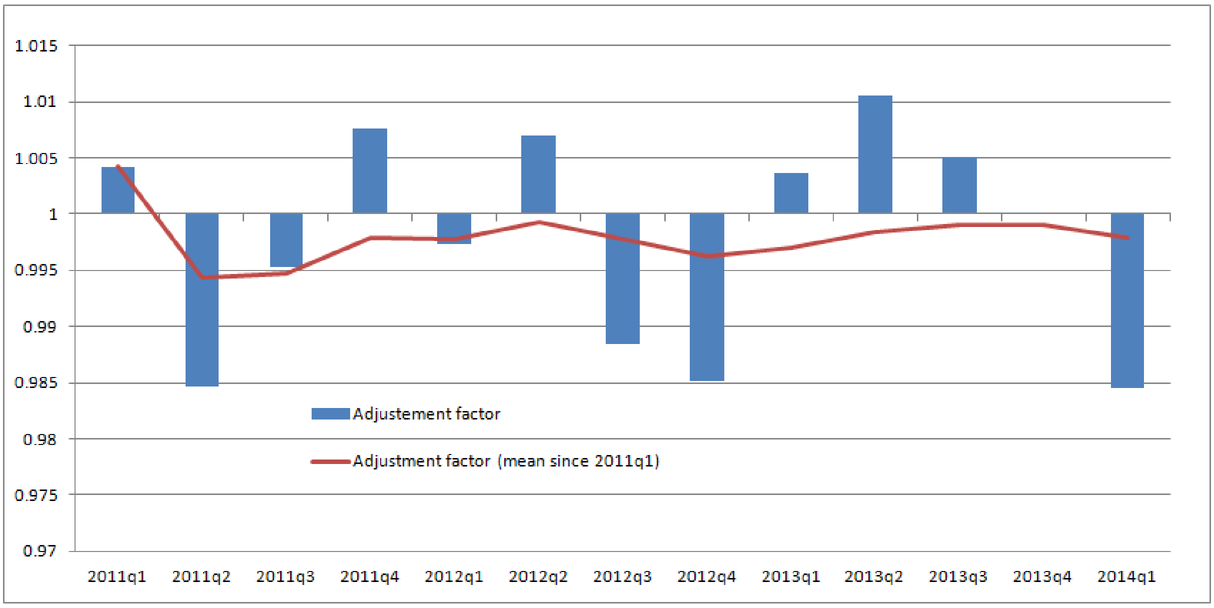
Some of this moderate impact can first and foremost be attributed to index design[17] because the hedonic adjustment is applied to the rotating segment of the index, whose weight within the index fluctuates between 12.38% and 14.61%. Next, more fundamentally, the RI is built on the basis of a random selection of dwellings, which means that the values assumed by characteristics of incoming and outgoing dwellings fluctuate around the mean values that characterise the housing population. As the characteristics of the housing population evolve slowly, these values are stable over two years[18]. In this case, the direction of the adjustment is not systematically positive or negative and, over time, variations in quality will cancel each other out (the adjustment factor will then fluctuate around a value of 1, which corresponds to a zero correction). By contrast, the effect of age, which is one of the characteristics taken into account, stands out as an exception as it is systematically positive. No outgoing dwelling may be less than two years old whereas incoming units may be new. Consequently, the expected adjustment factor will fluctuate around a value that is a shade higher than 1. In the short

[15] See Graph 4 and Appendix 7.3
[16] For unadjusted change between -0.44% and +0.96%.
[17] The index's characteristics were outlined in the previous section, and the breakdown into a panel segment (B) and a rotating segment (AC) is shown in Appendix 7.4
[18] The time interval between selection of incoming and outgoing dwellings, in the majority of cases.

term, quality variations do not cancel each other out, which accounts for the sizeable impact that adjusting may have on the index's quarterly change. Quality adjustments to the RI are thus chiefly an issue for short-term change in rents; in the longer term, the impact is marginal[19],[20]. Moreover, since the sample is large (with some 1,500 observations entering into components A and C), the adjustment factor's dispersion around its mean value is bound to remain moderate.

Graph 5 shows that real change in the adjustment factor does indeed exhibit a mean value close to 1 (0.9979)[21] and that this fluctuates between 0.984 and 1.011. However, the downswing to below 1 contradicts the presence of a unique, positive systematic effect associated with the "age" characteristic, which ought to produce a mean value slightly above 1. The presence of elements having a systematically negative impact can be suspected, even if the analysis period is limited to only 13 observations (which blurs distinction between random and systematic effects). The breakdown of the adjustment factor into factors associated with each characteristic will later on make it possible to analyse the reasons relating to this (see Section 4). Lastly, it should be further emphasised that unadjusted changes are weak and that, even though the adjustment factor fluctuates moderately around 1, it may have a sizeable influence on the adjusted change for a single quarter[22].

Graph 5: Adjustment factor (quarterly value and mean value)[23]



If the rotating segment in the panel (segment AC) is studied separately, the adjustment's impact is more marked in the short term but, at the same time, is still limited over the longer term. As such, the mean change in the component shifts from +0.83% to +1.03% after adjustment.

[19] This remark is not valid for adjustments applied in the context of personal computers. Selection of observations in this respect is not random (best-seller) and population characteristics change rapidly (and positively). As such, it is expected that the factor's mean value in this respect will be markedly higher than 1 (reflecting "quality" that is systematically higher for incoming units in relation to outgoing ones), possibly rising over time if the gap widens.
[20] This observation also implies that the influence of "poor" coefficient estimates is marginal over the longer term. A higher (or lower) coefficient will magnify (or dampen) fluctuations in the adjustment factor without undermining the trend towards a value of 1 so long as population characteristics are stable.
[21] Since adjusted change corresponds to unadjusted change / (adjustment factor), an adjustment factor higher (or lower) than 1 leads to a lower (or higher) change.
[22] For example, the minimum factor, 0.984, observed in the 1st quarter of 2014 implies a change in the rotating segment increased by approximately +1.6%. All in all, despite an apparently moderate adjustment factor, the rise in the rent index is subject to a 10-fold increase.
[23] See Note 21.

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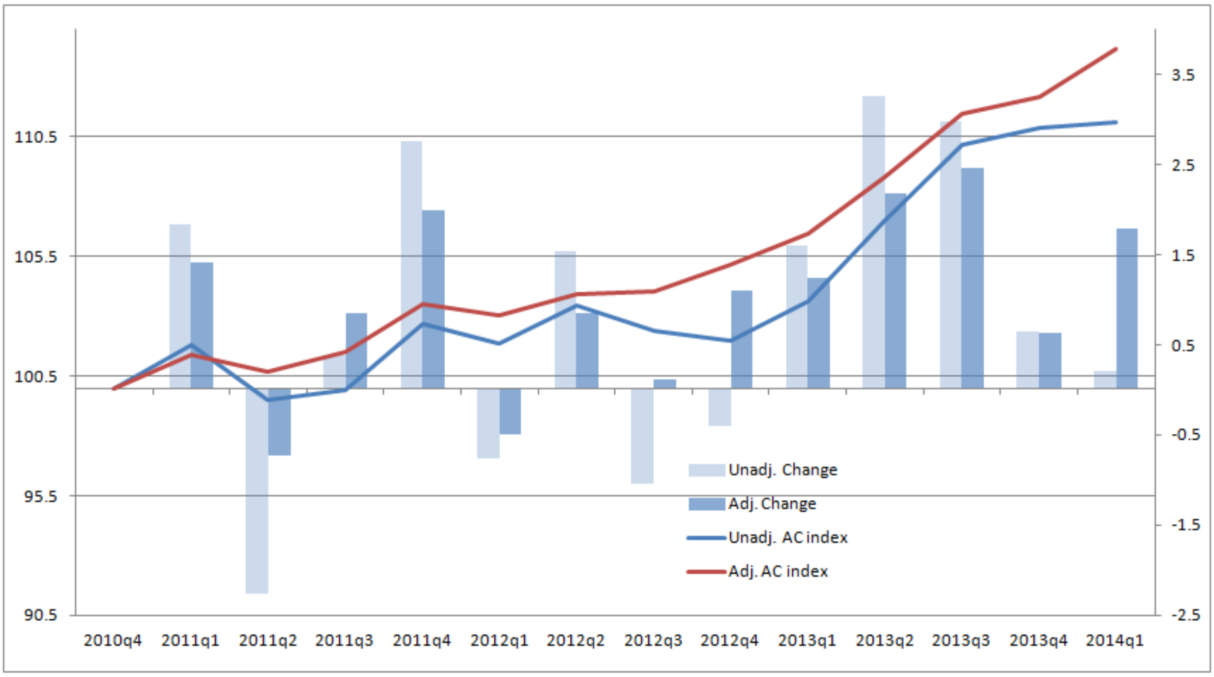
Graph 6: Unadjusted and adjusted indices for AC segment (left-hand scale) and change (right-hand scale)



Regarding individual quarters, adjusting leads to deviation relative to unadjusted change (between -1.08% and +1.58%[24]), which is once again distributed more or less evenly between positive and negative values. With the exception of three quarters (Q3 2011, Q4 2012 and Q1 2014), adjusting reduced the observed unadjusted change. For two quarters (Q3 2012 and Q4 2012), it changed the direction of the trend. The adjusted index diverged markedly in relation to the unadjusted index in the second half of 2012.

Graph 6 further shows that the adjusted data series has a steadier trend than the original series, which also shows up in the standard deviation of quarterly change:

	Adjusted AC index	Unadjusted AC index
Mean change[a]	+1.03%	+0.83%
Standard deviation[a]	0.94%	1.62%

[a] The two values are defined arithmetically.

Thus, the quality adjustment reduces the impact of fluctuations in characteristics arising from the random selection of replacements within the sample. The role of change in housing characteristics within the unadjusted change of the AC component can also be demonstrated by comparing the direction of the adjustment, measured by the inverted adjustment factor[25], and that of unadjusted change. If the characteristics considered were deemed to be unique determinants in the change in rents and that their implicit prices had not changed since the start of the estimation period, a perfect negative correlation[26] ought to appear between the two variables, and the adjusted change should be zero. This theoretical relationship is represented by the black line on Graph 7. The graph clearly shows that the adjustment in the vast majority of cases moves counter to the change in the unadjusted index (11 of 13 observations), which accounts for representation within quadrants I and III. The exceptions are Q3 2011 and Q1 2014 (quadrant II). A drop in the unadjusted index generally implies a positive quality adjustment and vice versa. Therefore, rents trend on the whole in the same direction

[24] For unadjusted change between -2.26% and +3.27%.

[25] As a reminder: $I_t^{adj} = I_t^{unadj} \cdot \frac{1}{\text{adj. factor}}$

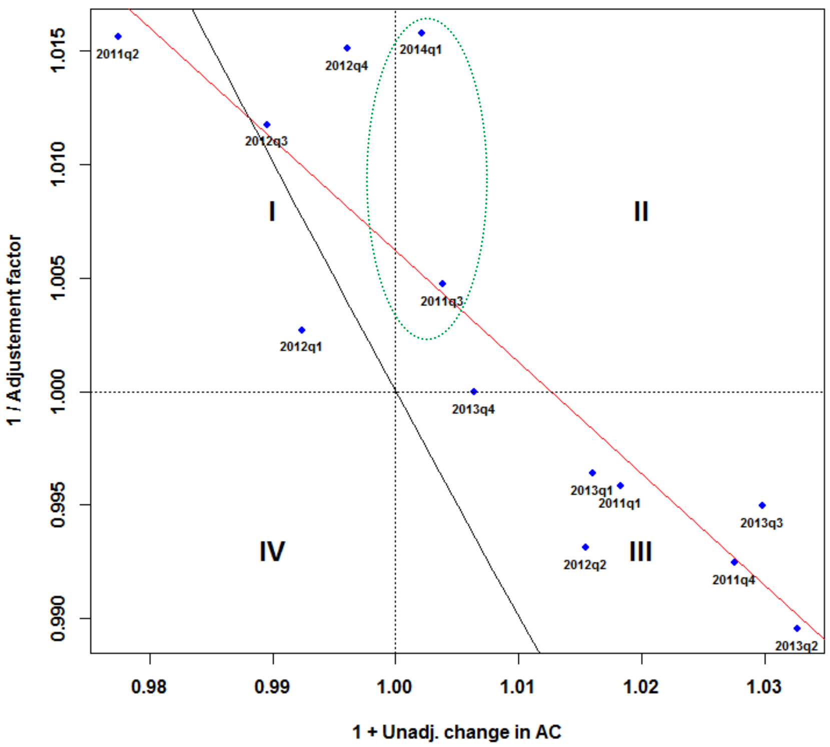
[26] In fact (1 / adjustment factor) = 1 / (1 + unadjusted change in AC) .

as housing characteristics. However, the correlation is not perfect, as illustrated by the red line, [27] which deviates from the "theoretical" black line. Although rents shift in the same direction as housing characteristics, they are also influenced by the following:

- By other factors not accounted for in the quality adjustment (e.g. differences in lease duration)
- By change in the implicit price of characteristics.

As such, change in the AC segment is only partly offset by the adjustment (the red line's slope is lower than the black line's) and its adjusted value reflects shifts in these various elements.

Graph 7: Unadjusted change and direction of adjustment



4 Breakdown of adjustment

4.1 Overall breakdown

For cell i and modelling of type $\ln(y) = \propto + \beta_1 X_1 + \beta_2 \ln(X_2) + \varepsilon$, the adjustment factor can be split into a product of factors associated with each characteristic[28]:

$$\hat{g}_{C,i}^{t} = \underbrace{\left[\frac{\prod_{j=1}^{n_{C,i}^{*t}} e^{X_{1,t}^{j} \frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} e^{X_{1,t-1}^{k} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}} \right]^{\beta_1}}_{Factor\ related\ to\ X_1} \cdot \underbrace{\left[\frac{\prod_{j=1}^{n_{C,i}^{*t}} X_{2,t}^{j\ \frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} X_{2,t-1}^{k\ \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}} \right]^{\beta_2}}_{Factor\ related\ to\ X_2}$$

[27] A regression of (1 / adjustment factor) on (1 + unadjusted change in AC) results in an adjusted R2 of 0.73 and a coefficient of – 0.49, even though so few observations make it insignificant.

[28] Further details can be found in Appendix 7.5.

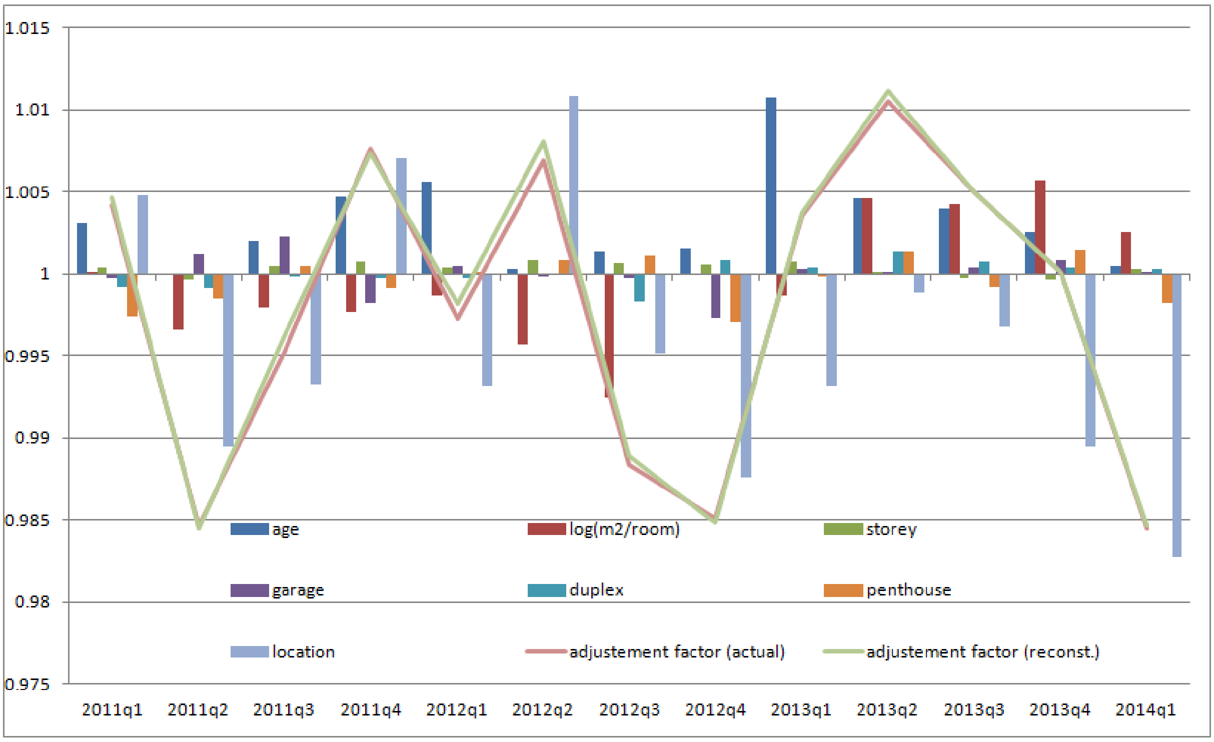
For variables associated with location, which are treated on a combined basis in the form of hectare-related values, the factor becomes:

$$\frac{\prod_{j=1}^{n_{C,i}^{*t}} e^{Hectare\_value_{2003}^{j} \frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} e^{Hectare\_value_{2003}^{k} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}$$

Each specific factor is then aggregated so that it can be analysed at an overall index level[29]. If the breakdown of the adjustment factor is exact at cell level, the regrouping thereof in terms of the total is approximate, and the resulting deviations are still minor[30].

Graph 8 (along with the values shown in Appendix 7.5.3) clearly shows that the factor relating to the dwelling's location is the most important factor within the adjustment. Regarding structural variables, age and size per room are the key factors. The factor associated with the dwelling's location also often has a negative orientation, and the observed downswing in the adjustment factor to below 1 noted in the previous section should be investigated within this factor.

Graph 8: Change in breakdown of adjustment factor



Detailed change in these various factors is analysed in the following sections.

4.2 Structural variables

4.2.1 Age

The "age " factor shows systematically positive values, in keeping with its nature. As stated previously,

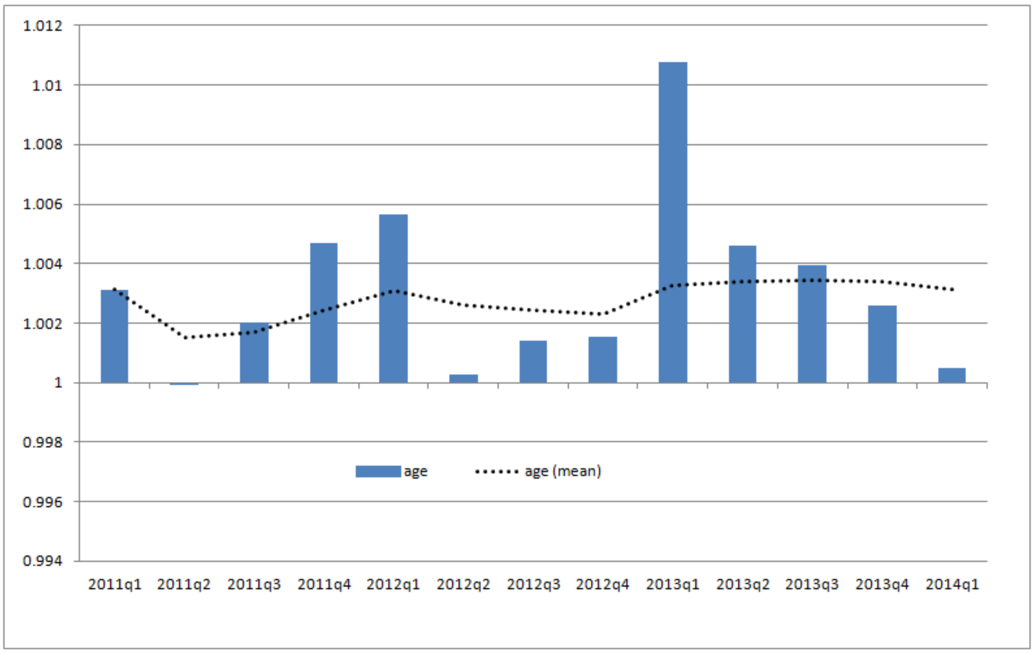
[29] Also see Appendix 7.5.

[30] For information, the actual adjustment factor and that reconstituted using the product of combined factors are represented on Graph 8. Findings indicate that the approximation is reasonable, with deviations between the actual factor and the factor obtained by multiplying individual combined factors fluctuating between -0.03% and + 0.12% in the Q1 2011- Q1 2014 period.

no outgoing dwelling can be less than two years old, whereas incoming units may be new. As age generally has a negative influence on rent, replacing a unit by a newer (or older) one implies a positive (or negative) adjustment factor. As such, the proportion of incoming new properties will be decisive for the value of this factor, which fluctuates between 0.999 and 1.011 for a mean of 1.003 (with the median also at 1.003).

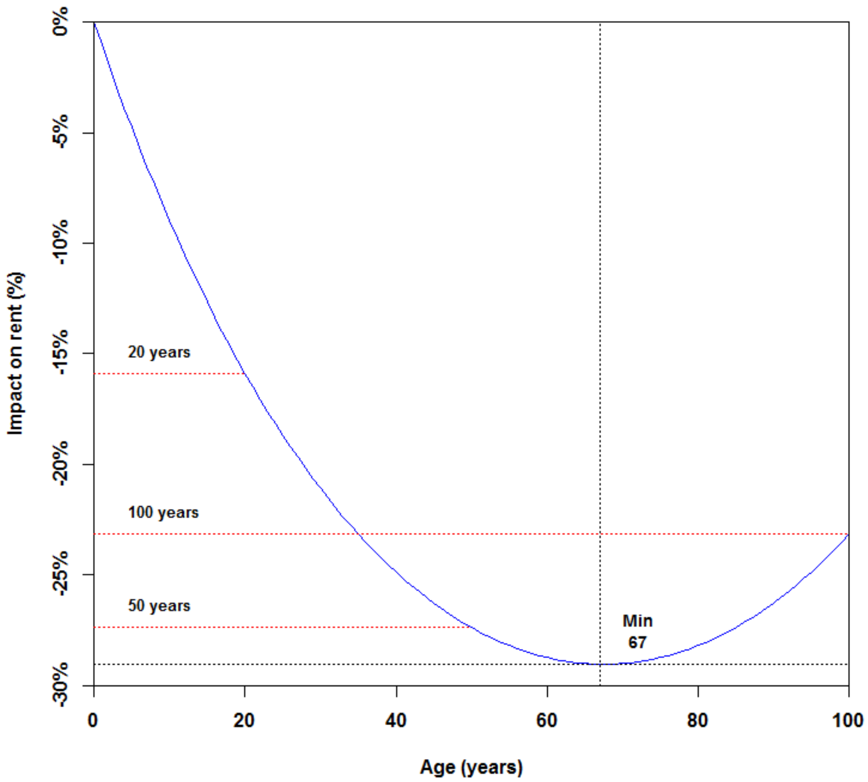
However, modelling age within our hedonic model is not linear but rather quadratic, as indicated by Graph 10 [31]**.** The negative impact of age on rent first of all rises to a peak at a value of 67 years (approximately –30%). Past 67 years, it starts declining, with ageing implying a less severe discount[32]. In certain cases, replacement with a newer dwelling may have a negative impact on the adjustment factor. For example, replacing a 100-year-old unit with one that is 50 (illustrated in Graph 10) suggests an adjustment factor of 0.945 (approx. -6%), whereas replacing a 50-year-old unit with one that is 20 implies a factor of 1.16 (approx. +16%).

Graph 9: "Age" factor



[31] According to the modelling selected, the impact of building age on rent as a % is given by ($e^{-0.0101\cdot \hat{a}ge+0.0000751\cdot \hat{a}ge^2}-1$).
[32] Koev (2003) distinguishes two elements within the age effect: depreciation, which is negative, and a so-called "vintage" effect, which is positive. The depreciation effect takes into account the use of better design and building techniques, which are a feature of newer properties. The "vintage" effect reflects architectural features that may be sought after in older properties. The second supplants the first as from 67 years, beyond which each extra year results in higher rent.

Graph 10: Impact of age on rent



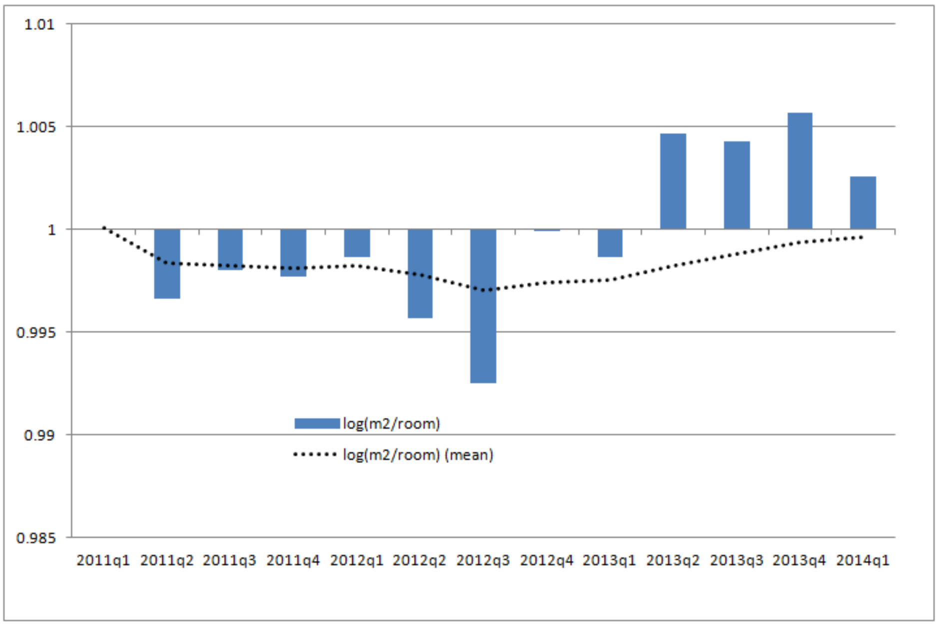
4.2.2 Size

The "size" factor (m^2/room) tends to hover around 1, and its distribution relative to 1 is well balanced (8 periods > 1 and 5 periods < 1). Data from structural surveys indicate stability in floor area over 2 years, which is what accounts for this trend.

Surface (m2)	2000	2010	2012
< 60	18.6%	18.0%	17.4%
60-79	22.4%	20.6%	21.6%
80-99	21.0%	19.9%	20.5%
100-119	12.8%	13.9%	13.8%
120-159	14.8%	16.5%	16.0%
>= 160	10.4%	11.1%	10.7%

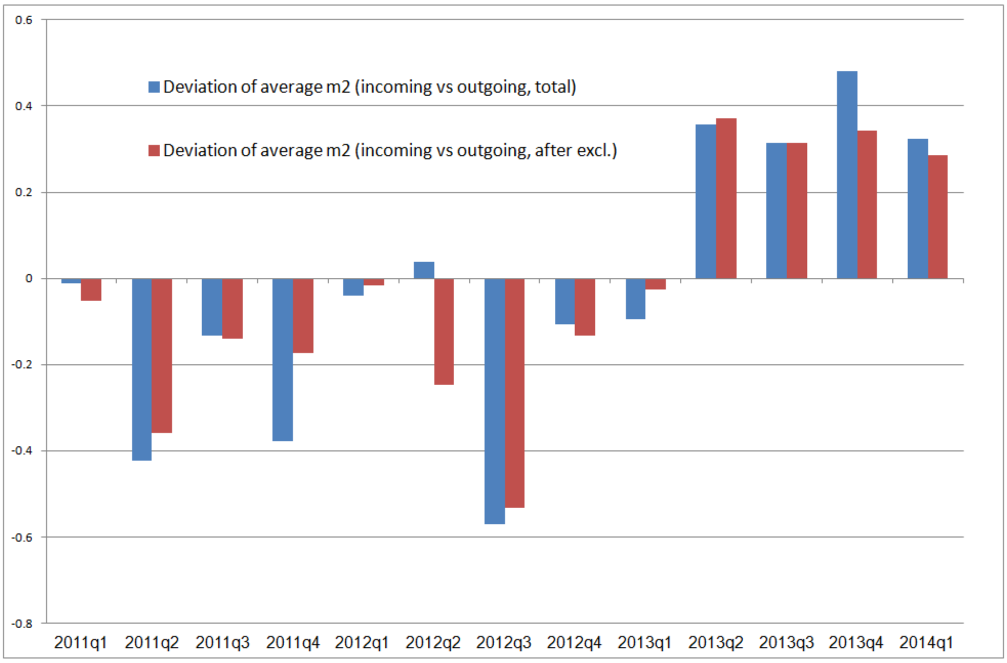
However, the "size" factor operates according to two distinct phases: a first phase where incoming units systematically show lower values (Q2 2011–Q1 2013), then a second phase where the opposite occurs (Q2 2013–Q1 2014).

Graph 11: "Size" factor



Changes in this factor correspond to shifts that can be observed in terms of deviations between average surface area within the incoming cohort and the average surface area within the outgoing cohort (Graph 12)[33]. Excluding some observations from the factor's calculation has only a limited impact in general.

Graph 12: Average surface areas



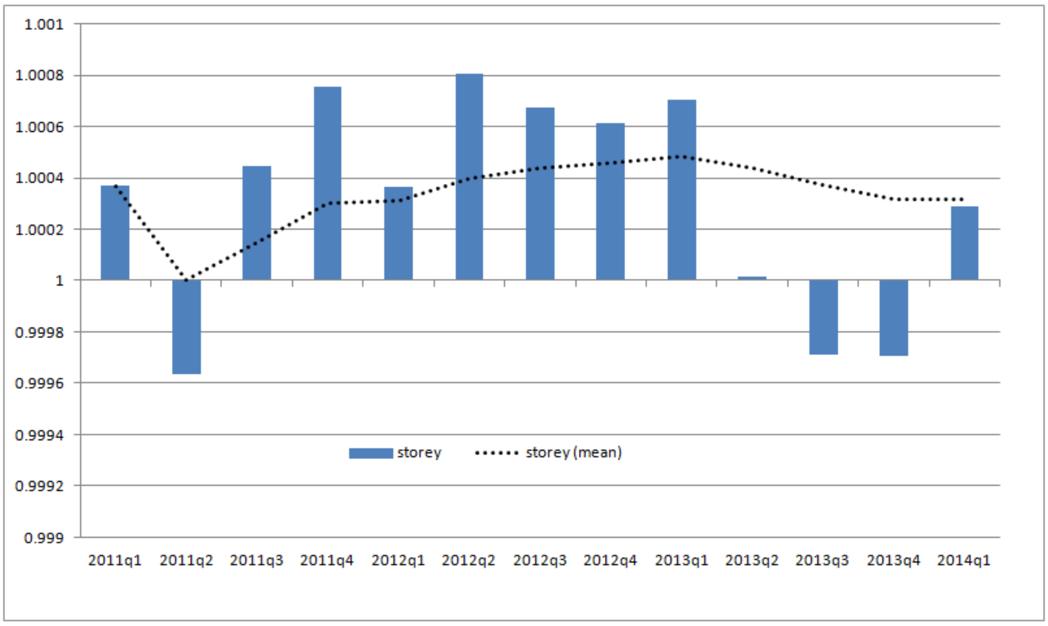
Analysis of the "size" factor cannot mark out any element calling into question the random nature of its change pattern.

[33] Calculating these averages takes into account the weight of the observations, which are also adjusted in such a way as to reflect the weight of the cells to which they belong. A fuller explanation of this is given in Section 4.3 (analysis of "location" factor).

4.2.3 Storey

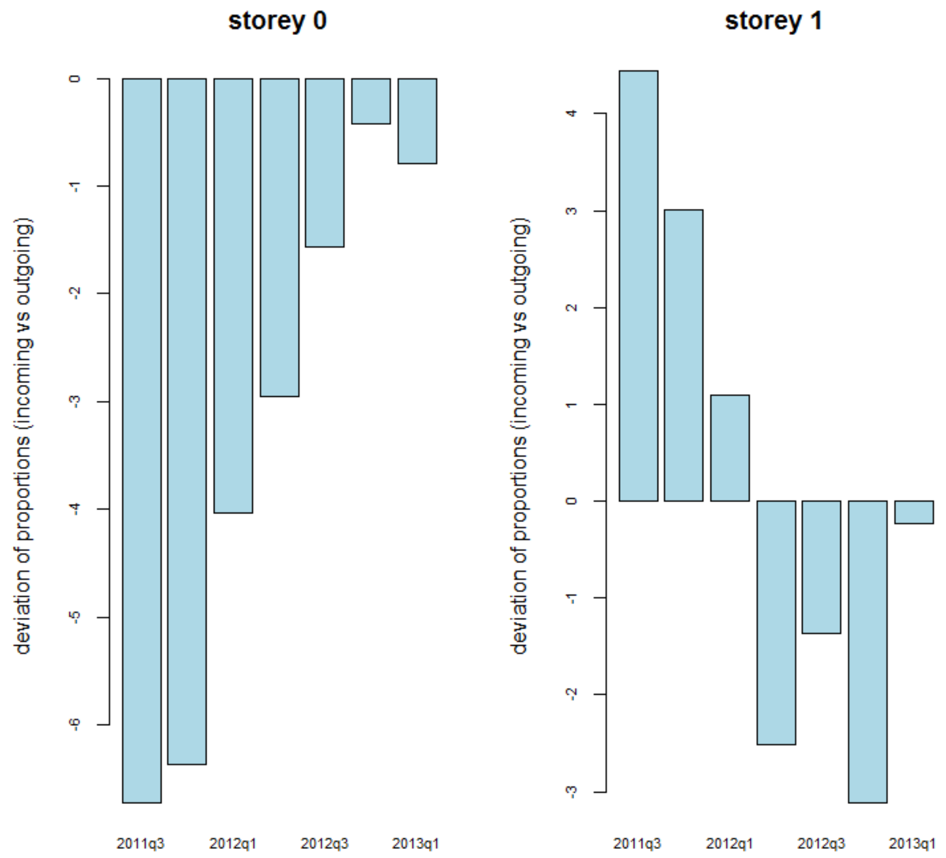
The "storey" factor does not exhibit a change pattern clearly compatible with a random selection within a stable population. The vast majority of values in this respect are higher than 1 (10/13), though straying only moderately from this mark (factors are distributed between 0.99964 and 1.0008, with an average of 1.0003). The Q3 2011–Q1 2013 period has a considerable influence, with a succession of 7 quarters showing a positive factor.

Graph 13: "Storey" factor



Regarding the different values of this variable ([0; 20]), deviations between the proportion within the incoming cohort and the proportion within the outgoing cohort were observed in the Q3 2011–Q1 2013 period. They show a systematically negative deviation for dwellings with a value of 0 (ground floor), whereas deviations are more often positive for the upper stories. The share of ground-floor apartments was thus systematically lower with incoming as opposed to outgoing units over this period, which implies a factor higher than 1 (effect of upper storey is positive). Furthermore, first-storey apartments appear under-represented in the second part of this period.

Graph 14: Distribution of deviations (storey = 0 and 1)



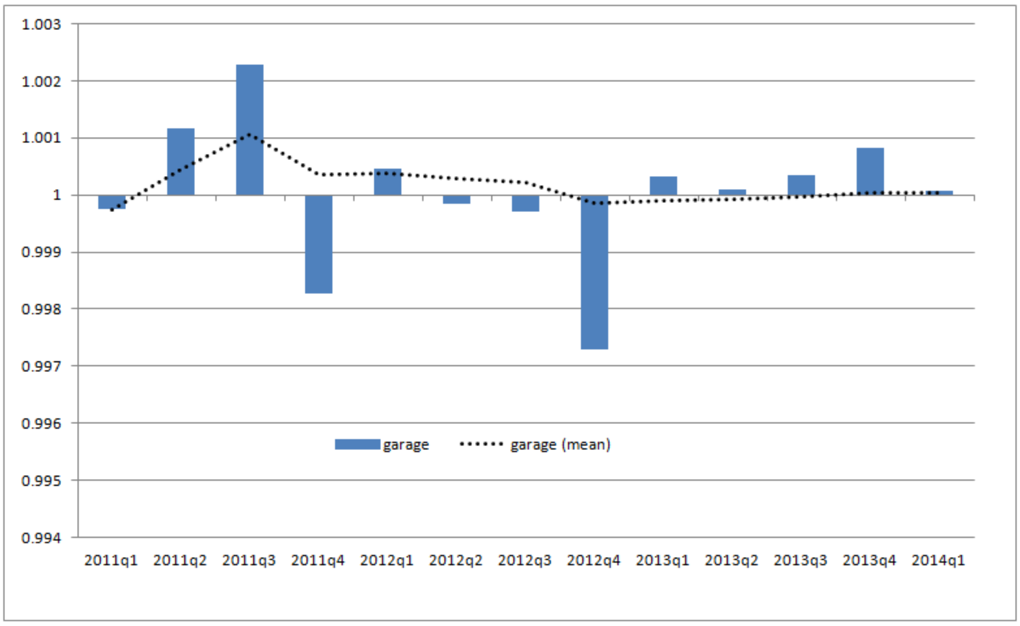
The systematic under-representation of ground-floor dwellings within the outgoing group is especially surprising in that the treatment applied to missing values implies imputation of a 0 value. As this can be progressively corrected over the two survey years, values within outgoing dwellings should present fewer imputed values (equal to 0), and a slight degree of over-representation of ground floors within incoming units in principle would be expected. Analysis has not highlighted a particular reason for these observations, which are nonetheless not problematic given the values bordering on 1 assumed by the "storey" factor.

4.2.4 Garage, duplex, penthouse

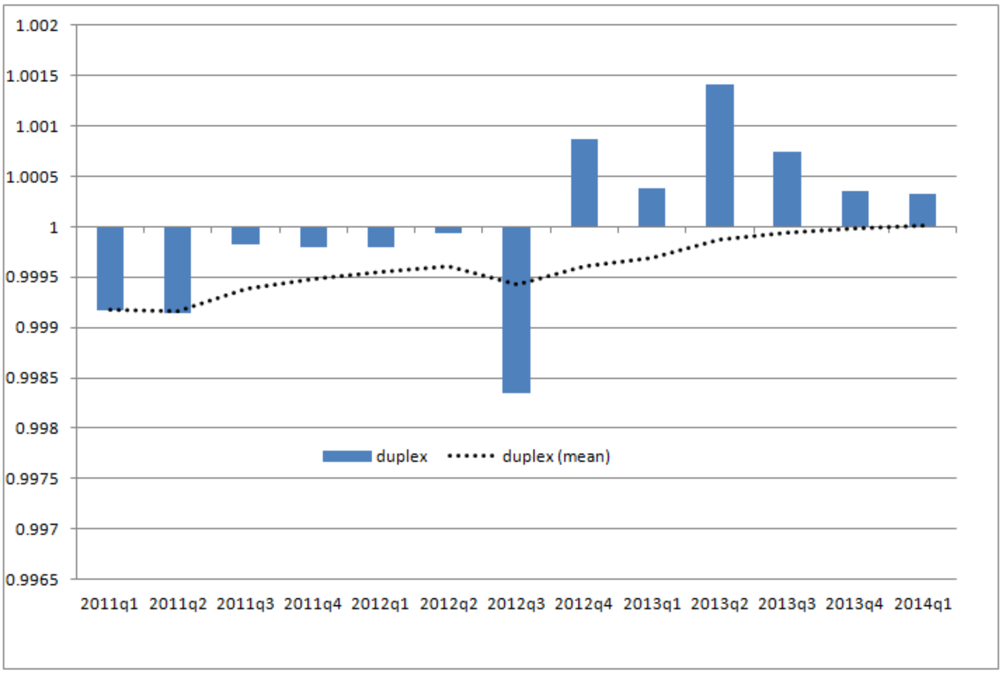
Factors relating to the characteristics "garage" (price of garage included in lease), "duplex" (split-level apartment) and "penthouse" (top-floor flat) all show change patterns compatible with a random selection of dwellings within a stable population. Positive and negative factors are well balanced and their average value tends towards its expected reading of 1 (absence of correction).

The "duplex" factor shows two distinct phases: a first phase where incoming units systematically contain fewer duplex units (Q2 2011–Q1 2013), then a second phase where the opposite occurs (Q4 2012–Q1 2014).

Graph 15: "Garage" factor



Graph 16: "Duplex" factor



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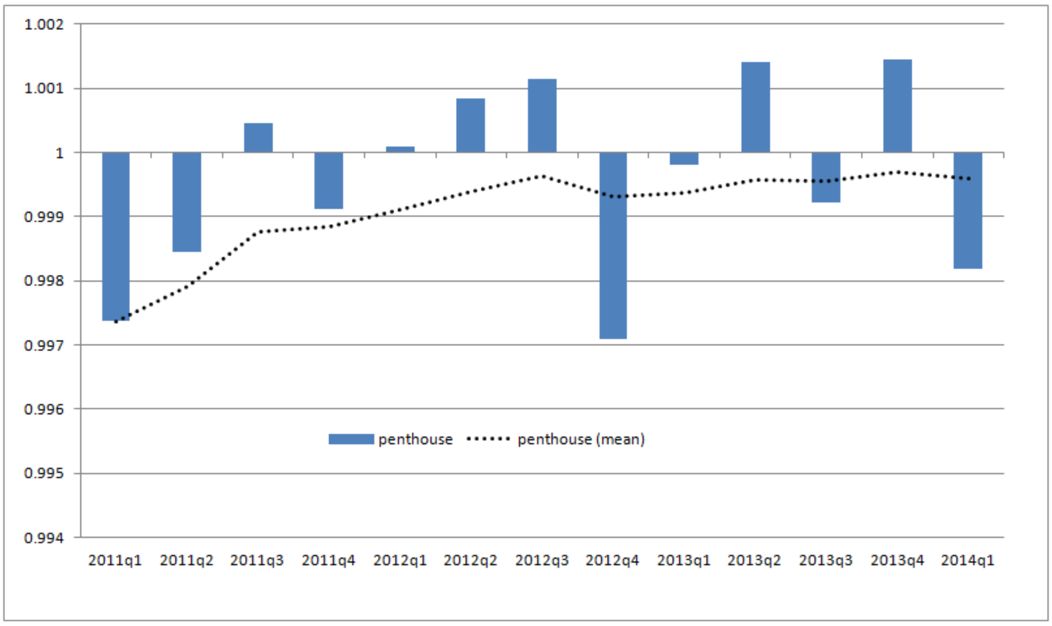
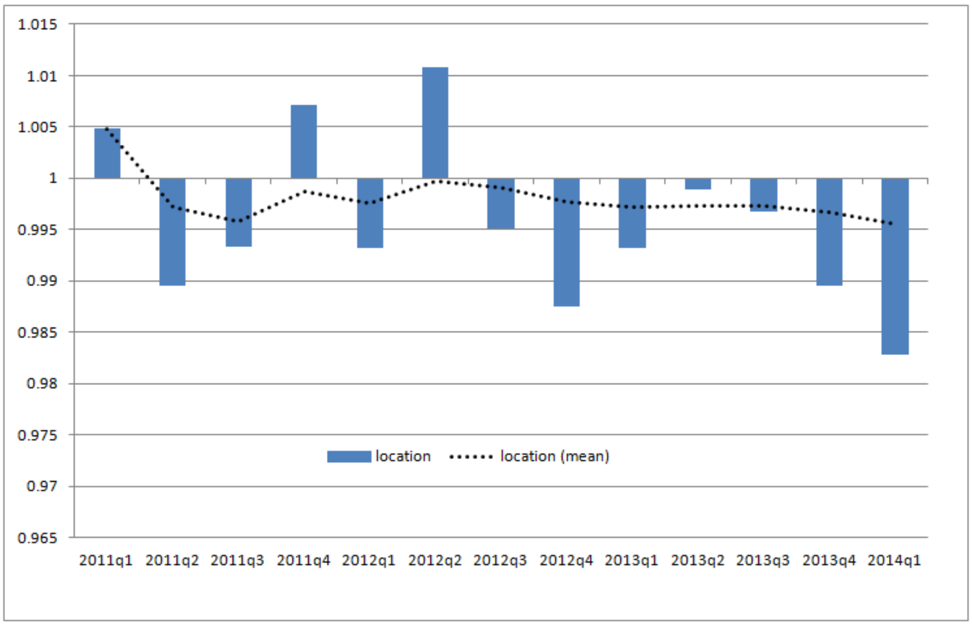
Graph 17: "Penthouse" factor



4.3 Location

The "location" factors converges towards a value of 1 as far as Q2 2012, then seems to diverge with a succession of 7 negative adjustments. Its distribution in relation to 1 is not well balanced, with 10 periods below 1 and 3 periods higher than 1. Given its dominant influence on the hedonic adjustment, its change pattern will be analysed in greater depth in this section.

Graph 18: "Location" factor



A dwelling's location relates to several factors. As such, analysis is simplified by examining the geographical distribution of units as an indicator of location. However, this distribution is more suitable for macro elements as opposed to factors pertaining to micro location.

As no significant shift is expected in the geographical split of the housing stock, a trend value other than 1 cannot in principle be warranted. This stability in the geographical distribution of the housing stock is confirmed by the structural survey data as shown below:

Major region	2000	2010	2012
Lake Geneva region	19.7%	19.7%	19.8%
Espace Mittelland	22.3%	22.1%	22.1%
North-Western Switzerland	13.0%	12.8%	12.8%
Zurich	16.8%	16.6%	16.6%
Eastern Switzerland	14.6%	14.7%	14.7%
Central Switzerland	8.4%	8.7%	8.7%
Ticino	5.2%	5.3%	5.3%

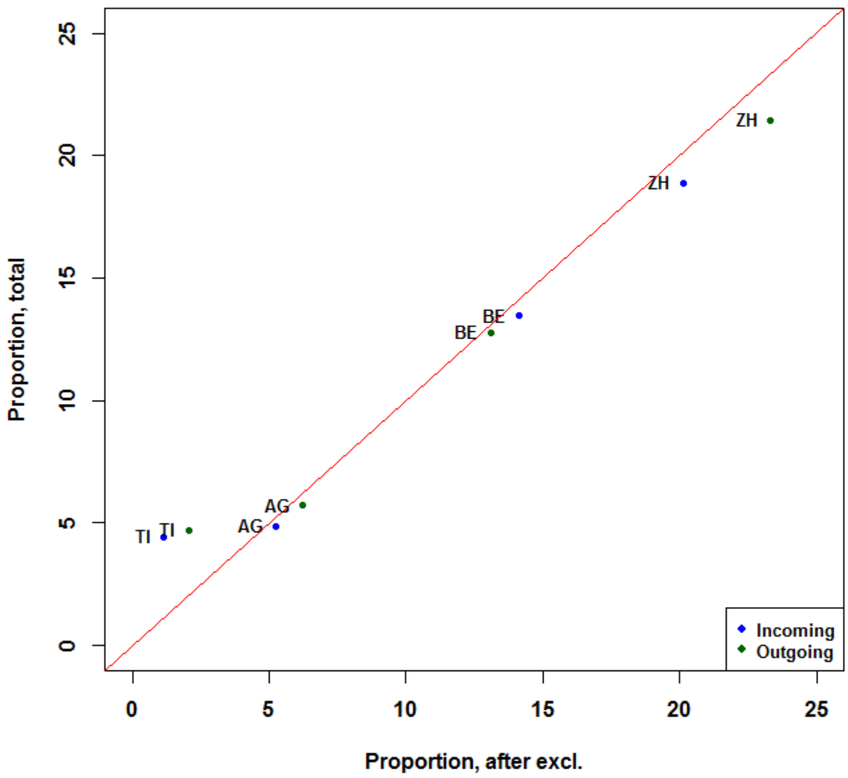
A trend value below 1 implies a share of regions with lower rents within the incoming cohort that is systematically higher than that of outgoing units, which is not realistic on the basis of the above figures. Two main reasons could account for a misleading trend by the adjustment factor:

1. An effect arising from the survey frame. The trend in the adjustment factor towards 1 relies on a random selection within a stable population, which is represented by the survey frame. If this frame changes in a different way to that of the population it supposedly represents, it may be that the regional structure that it contains is no longer stable. The current survey frame of the RI is founded on a list of fixed-line telephone numbers, and comparisons carried out on a regular basis with the alternative frame based on registers of persons indicate that some specific regions may be affected by coverage problems (e.g. Geneva and Ticino). However, such an effect would not be specific to the adjustment factor but rather would affect the whole index. Bearing this in mind, the adjustment factor would be coherent with the unadjusted index. Moreover, this effect is partially adjusted for when calculating observation weights, which take into account the distribution of dwellings by major regions.

2. An effect relating to the exclusion of some observations. As touched upon in Section 2.2.2, some observations are not included in the calculation of the adjustment factor due to a lack of information on the dwelling's surface area or its precise location. Furthermore, the rotating segment of some cells is excluded from the index calculation owing to insufficient observations. Bias can be created if these exclusions more systematically concern certain regions and affect incoming and outgoing units differently. Such an effect would be specific to the adjustment factor, which would then become incoherent with the unadjusted index.

The effect arising from the exclusion of some observations was analysed over the Q1 2012–Q1 2014 period (9 quarters) by comparing the breakdowns per canton of total incoming/outgoing units (n) and the incoming/outgoing units used for calculation of the adjustment factor (n*). These distributions take into account both the survey weight of different observations and the weight of their respective cells. In practical terms, an observation is counted as $\hat{p}_{j,t} = p_{j,t} \cdot \left[\propto_i \cdot \frac{\sum_j p_{j,t}}{\sum_{j \in i} p_{j,t}} \right]$ observations, with its survey weight $p_{j,t}$ calibrated to the weights of cells $\propto_i$. The comparison shows that exclusion of some observations is not neutral as regards the spatial distribution of dwellings. Two cases in particular stand out: Ticino, which is systematically under-represented within the observations taken into account (by 2.5-3%, versus a 4% share of total observations), and Zurich, which is systematically over-represented therein (by some 1.5%, versus a 21% share of total observations), as indicated in the example of the period Q1 2014 (Graph 19, cantons BE and AG are also shown for purposes of comparison). These cases of over- or under-representation concern incoming as much as outgoing dwellings and do so in similar proportions. No other cantons show such a marked effect, even though the impact of observation exclusion often appears systematic.

Graph 19: Proportions, Zurich and Ticino (Q1 2014)



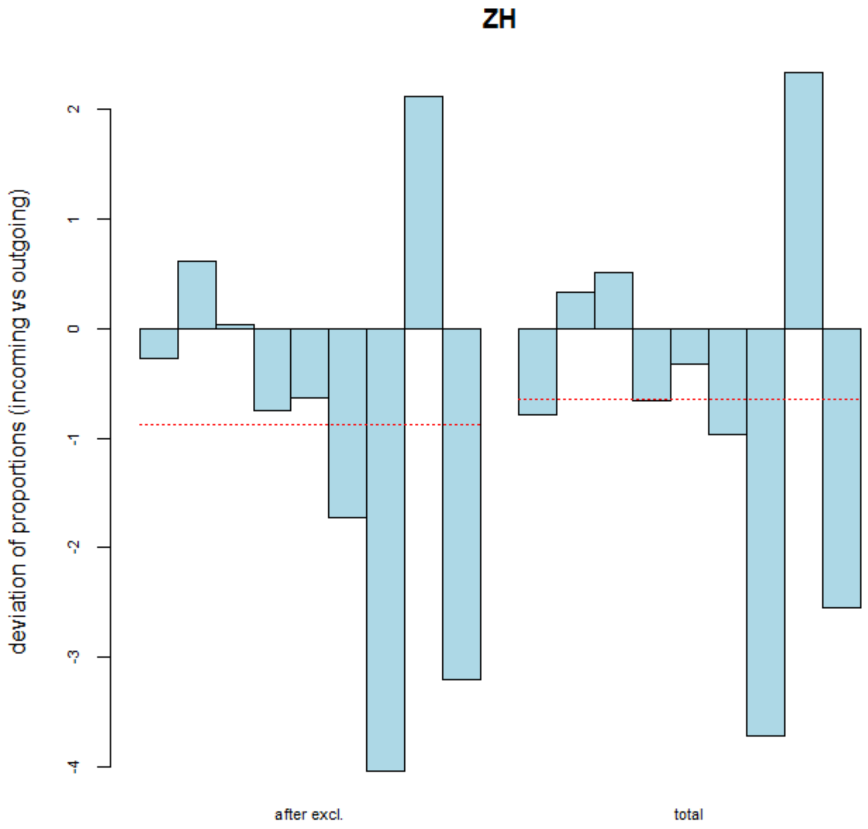
However, it is more relevant to analyse the impact of observation exclusion on the deviations between proportions within incoming dwellings and proportions within outgoing dwellings, which along with the regression coefficient are decisive for adjustment factors[34]. A positive deviation for a low-rent region (i.e. a higher proportion of this region within incoming as opposed to outgoing dwellings) is thus compatible with a factor below 1 whereas a negative deviation corresponds to a factor higher than 1. The line of reasoning is the opposite for high-rent regions. An effect relating to the exclusion of observations will be observed if it modifies the orientation or extent of these differences. In the first case, the factor's orientation is altered whereas the second case will influence its importance. The following table first and foremost allows for a comparison between the distribution of positive and negative deviations, before and after exclusion, for different cantons:

		Distribution of deviations (total)		
		Nb + > Nb -	Nb + = Nb -	Nb + < Nb -
Distribution of deviations (after exclusion)	Nb + > Nb -	AR, BE, FR, GE, GR, JU, OW, SH, SO, SZ, TG, UR, VD, ZG	GL	-
	Nb + = Nb -	AI	-	-
	Nb + < Nb -	TI	-	AG, BL, BS, LU, NE, NW, SG, VS, ZH

This comparison is also illustrated by the following chart showing the canton of Zurich:

[34] See description of a factor relating to a dummy variable in Appendix 7.5.1.

Graph 20: Compared distribution of deviations (Zurich)



For the vast majority of cantons, the distribution of deviations between positive and negative values does not vary fundamentally after exclusion of observations, though from time to time inversions are observable. Among the cantons for which modifications are observed, the latter are extremely limited and concern 1–2 periods. As such, excluding observations does not broadly modify the orientation of deviations or, consequently, the orientation of the factor.

By contrast, the factor's importance is influenced by the size and orientation of the exclusion impact. Generally, this is distributed evenly between positive and negative impacts[35] and, on average, is all the time moderate. However, the following cantons exhibit more frequent impacts in one or another direction, but as stated above, this does not modify the orientation of deviations:

Impact	BS	FR	GR	NE	OW	UR
Nb +	8	6	6	6	6	3
Nb -	1	3	3	3	3	6
Mean impact	0.09%	0.11%	0.06%	0.02%	0.05%	0.01%
Mean deviation (total)	0.02%	-0.11%	0.11%	0.05%	0.10%	0.06%

Impact	VD	ZH
Nb +	3	2
Nb -	6	7
Mean impact	-0.04%	-0.23%
Mean deviation (total)	0.29%	-0.65%

[35] A positive impact corresponds to a higher (lower) factor if the coefficient is positive (negative), whereas a negative impact corresponds to a lower (higher) factor.

Limitations and impact of hedonic adjustment for the rent index

Thus, if excluding some observations from the adjustment factor calculation is not neutral geographically speaking and may have an impact on the factor's value, analysis fails to highlight marked systematic effects relating to this exclusion[36].

In the end, analysis further indicates that the distribution of deviations between proportions within incoming and proportions within outgoing dwellings is not well balanced for some cantons, even prior to exclusion of observations (e.g. the case of Zurich, outlined above). The following table details the distribution of positive and negative deviation cases for these cantons:

Deviations	AG	AR	BE	GR	NE	NW
Nb +	2	7	6	6	3	2
Nb -	7	2	3	3	6	7
Mean	-0.23%	0.12%	0.34%	0.11%	0.05%	-0.16%

Deviations	OW	SH	SO	TG	ZH
Nb +	8	6	6	6	3
Nb -	1	3	3	3	6
Mean	0.10%	0.05%	0.07%	0.28%	-0.65%

The mean deviations are low, however, and while systematic effects cannot be ruled out as regards some cantons, the impact ought to be weak.

5 Conclusions

The analysis presented in this paper investigates for the first time the impact of adding a hedonic adjustment to the calculation of the Swiss rent index (RI). The following points sum up the primary conclusions that we believe can be drawn after 13 quarters. The main contributions of hedonic adjustment can first of all be described as follows.

- Hedonic adjustment is essential for a more accurate estimate of rent changes over the short term. As the RI is formed using a rotating panel, one-eighth of which is replenished every quarter, the random selection of dwellings for the purpose of this rotation creates fluctuations in the characteristics of the dwellings selected. Combined with stratification by age and number of rooms, hedonic adjustment can correct the impact of such fluctuations on the index. However, as characteristics of the housing population are stable over the medium term, the qualitative differences offset each other over time, and the adjustment's impact vanishes over the longer term.

- Compensation over time of quality differences implies a convergence in the adjustment factor towards a value of 1 (or, more precisely, slightly above 1, under the effect of a systematically positive "age" factor). Analysis of its change and its component are as a result worthwhile for the qualitative monitoring of the index calculation. The existence of systematic deviations relative to this trend must be analysed at the level of the various components, and may allow for the identification of problems arising from the survey framework, the dwelling selection method or the imputations carried out.

- By adjusting out the effect of differences in characteristics, hedonic adjustment can also limit the scale of problems arising from the selection of dwellings, making it a kind of fail-safe. For example, analysis of the "location" factor indicates that systematic effects on dwelling selection cannot be categorically ruled out in terms of geographical distribution. In this precise example, adjusting can take this into account, though with a factor diverging from its expected trend towards 1.

[36] Aggregated treatment of characteristics relating to location within values by hectare cannot be straightforwardly used at cantonal level to quantify an impact.

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However, our analysis has also highlighted the following limits:

- The impact of hedonic adjustment is limited by the use of a rotating panel wherein only 1/8 of the sample is renewed quarterly and concerned by the adjustment. A change in the scale of the replacements would alter this impact, with a higher (lower) degree of renewal implying a greater (lesser) need for adjusting.

- The various items used to build the index (survey framework, dwelling selection method, index stratification and imputations) have a high degree of influence on the effectiveness and role of hedonic adjustment. Using stratification is a simple means of reducing the weight burdening the adjustment as it adjusts out marked qualitative differences.

- Imputations carried out may have an impact on adjustment quality. This is because the imputed value of a characteristic differs from the actual value characterising the dwelling and can skew the adjustment carried out.

- Lastly, practical constraints arising from the adjusting are not necessarily neutral. Within the RI, this implies the exclusion of observations from the adjustment calculation whose geographical distribution differs from that of the full sample.

We would also be tempted to question the usefulness, or rather the significance, of this kind of model because effects on the total rate of inflation seem insignificant. Is the investment worth it? When developing the hedonic model, we were perfectly aware that sample size and surveying technique were factors that have a far greater impact on results than quality adjustments. But to guarantee a credible CPI (see introduction), it was important that we take our work to its logical conclusion. Since 2011, we have observed that the impact of the quality adjustment on rents against the whole CPI is practically zero. This may not always be the case. We have implemented a system capable of discerning and adjusting out any significant shift in the qualitative components of dwellings. Any future changes will therefore also be dealt with.

6 Bibliography

- Corinne Becker Vermeulen, Hans Markus Herren (2009), *Rents in Switzerland: sampling and quality adjustment*, paper presented to the 11th meeting of the Ottawa Group, Neuchâtel, 2009;
- Destatis (2009), *Handbook on the application of quality adjustment methods in the Harmonised Index of Consumer Prices*, Statistics and Science vol. 13, Statistisches Bundesamt, Wiesbaden 2009;
- Jan de Haan (2007), *Hedonic Price Indexes: A Comparison of Imputation, Time Dummy and Other Approaches*, Working Paper 2008/01, Center for Applied Economic Research, 2007;
- Hans Markus Herren (2010), *Introduction de l’ajustement de la qualité pour l’indice des loyers*, internal document, Neuchâtel, 2010;
- Eugen Koev (2003), *Combining Classification and Hedonic Quality Adjustment in Constructing a House Price Index* , paper presented to the 8th meeting of the Ottawa Group, Helsinki, 2004;
- Eurostat (2011), *Technical manual on Owner-Occupied Housing for Harmonised Index of Consumer Prices*, Eurostat, Luxembourg, 2011;
- Jack Triplett (2006), *Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes*, OECD Editions, Paris, 2006;
- Jean-Michel Zürcher (2011), *Zoom sur quelques indices particuliers : l’indice des loyers (IDL)*, internal document, Neuchâtel, 2011.

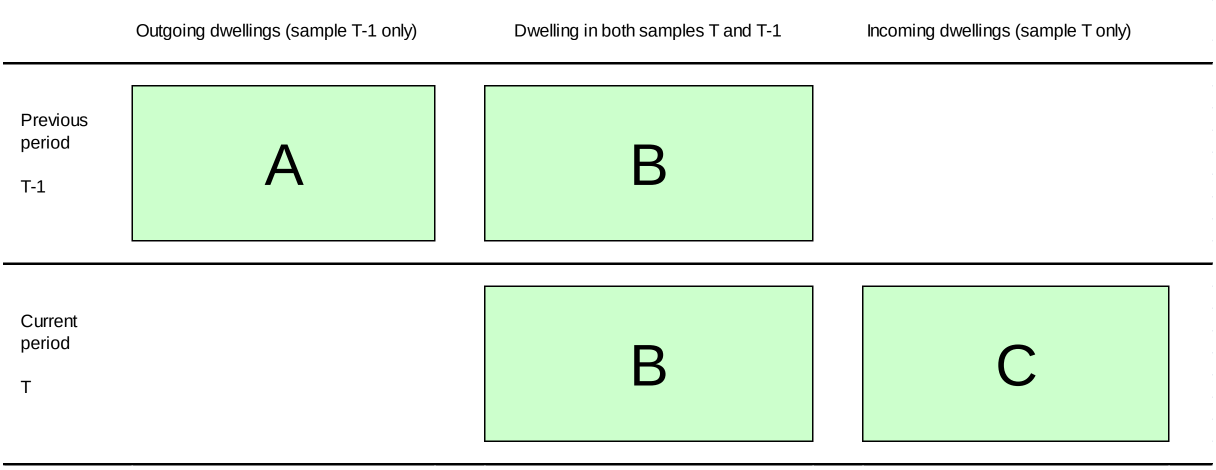
7 Appendices

7.1 RI calculation principles

The rent index relies on the estimation of indices within 24 cells defined through a combination of building age (four age classes) and number of rooms (maximum of 6). Their weights are represented as follows.

Age	Size					
	1 room	2 rooms	3 rooms	4 rooms	5 rooms	6 rooms
0 – 5 yrs	0.0716%	0.6107%	1.8844%	3.5481%	1.9302%	0.3411%
6 – 10 yrs	0.0890%	0.3902%	1.1707%	2.0941%	1.2777%	0.3087%
11 – 20 yrs	0.2795%	1.4704%	3.4181%	4.3026%	1.8424%	0.4814%
> 20 yrs	2.7708%	10.8714%	26.1738%	23.0583%	8.8722%	2.7426%

Within each cell, the following items can be broadly distinguished:



The following principles are applied for constructing the index:

i. Index calculation for cell (i)

$$I_i^t = \begin{cases} \frac{n_{B,i}^t}{n_{B,i}^t + n_{C,i}^t} I_{B,i}^t + \frac{n_{C,i}^t}{n_{B,i}^t + n_{C,i}^t} I_{AC,i}^t \ , & n_{C,i}^t \ and \ n_{A,i}^{t-1} \geq 3 \\ I_{B,i}^t & , \quad n_{C,i}^t \ or \ n_{A,i}^{t-1} < 3 \end{cases}$$

The index for a cell is based on the arithmetic combination of two indices, relating to the segment "pure panel" (B) and panel rotation (AC). If the number of observations is deemed insufficient within the segment AC (<= 3 for A or C), only the index calculated for segment B is taken into account.

ii. Index calculated for segment B, (cell i)

$$I_{B,i}^t = \frac{\left(\prod_{j=1}^{n_{B,i}^t} y_{j,t}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{B,i}^{t-1}} y_{k,t-1}{}^{p_{k,t}}\right)^{\frac{1}{\sum_k p_{k,t}}}} \ ,$$

where $n_{B,i}^{t}$ < $n_{B,i}^{t-1}$ because the latter also includes outgoing dwellings <u>excluding data slice 8.</u> Individual weights $p_{j/k,t}$ reflect the sampling design (probability of inclusion) and are adjusted to correct for non-response within the various strata. Furthermore, they are calibrated to the distribution of dwellings by regional clusters as observed through the 2012 structural survey.

iii. Index calculated for segment AC, (cell i)

$$I_{AC,i}^{t} = \frac{\left(\prod_{j=1}^{n_{C,i}^{t}} y_{j,t}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{t-1}} y_{k,t-1}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}} \cdot \hat{g}_{C,i}^{t}} = \frac{\left(\prod_{j=1}^{n_{C,i}^{t}} y_{j,t}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{t-1}} y_{k,t-1}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}}} \cdot \frac{1}{\hat{g}_{C,i}^{t}}$$

With:

- $n_{A,i}^{t-1}$= number of outgoing dwellings in data slice 8
- $\hat{g}_{C,i}^{t} = \frac{\left(\prod_{j=1}^{n_{C,i}^{*t}} \hat{y}_{j,t,2003}{}^{p_{j,t}}\right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{*t-1}} \hat{y}_{k,t-1,2003}{}^{p_{k,t-1}}\right)^{\frac{1}{\sum_k p_{k,t-1}}}}$ (adjustment factor)
- $\hat{y}_{j,t,2003}$, $\hat{y}_{k,t-1,2003}$= estimate as t (t-1) of rent j (k) by hedonic model (model estimated on the basis of data recorded in 2003)
- $n_{C,i}^{*t}$ < $n_{C,i}^{t}$ and $n_{A,i}^{*t-1}$ < $n_{A,i}^{t-1}$, only rents for which <u>all</u> information necessary for the hedonic adjustment is taken into account for the adjustment.

iv. Calculation of the overall index by combination of (k) different cells i:

$I^{t} = \sum_{i=1}^{24} \propto_i I_i^{t}$, where α_i corresponds to the weight of the 24 cells presented at the beginning of description.

7.2 Specification of hedonic regression

The estimated hedonic model is of type $\ln(y) = \propto + \beta_1 X_1 + \beta_2 \ln(X_2) + \varepsilon$. Key indicators associated with the estimation are:

Number of observations	91,243
Adjusted-R2	0.663
Standard error of the regression (RMSE)	0.227

As such, 66% of the variance in the rents logarithm is accounted for by the model and about 2/3 of the observed rentals are situated within an interval of +/- 23% around their estimated value.

The variables in the model are listed below, the reference (LOG) indicating that they are logged (type X_{2}). Dummy variables are also marked with a (D):

Variable	Description	Estimated coefficient [1]	Type of factor
Constant	-	2.6586***	-
Age	Age of building (difference between the survey year and the year of construction)	-0.0101***	Structural

Age (squared)	Age squared of the building	0.0000751***	
Living area/number of habitable rooms (LOG)	Living area in m2 (with kitchen and bathrooms)/Number of habitable rooms (excluding kitchen and bathrooms)	0.3733***	
2 rooms (D)	Specific constant if 2 rooms	0.4106***	
3 rooms (D)	Specific constant if 3 rooms	0.6832***	
4 rooms (D)	Specific constant if 4 rooms	0.9002***	
5 rooms (D)	Specific constant if 5 rooms	1.0843***	
6 rooms (D)	Specific constant if 6 rooms	1.2115***	
Storey	Storey on which dwelling is located	0.0045***	
Garage included (D)	The apartment has a garage and rent is included in the dwelling's net rent	0.066***	
Penthouse (D)	Penthouse accommodation (top-floor accommodation, with roof terrace)	0.1655***	
Duplex (D)	Duplex apartment (on 2 floors)	0.0669***	
Lease term (years) [2]	*Time elapsed on lease (in years)*	*-0.0077****	
Cooperative, Confederation, cantons, municipalities[2]	*The owner is a cooperative, the Confederation, a canton, municipality or city*	*-0.1664****	
Distance from lake front <200m (D)	Specific constant if the minimum distance between the hectare on which the dwelling is located and the lake is less than 200m (as the crow flies)	0.0061***	Micro location
Distance from the lake (km)	Minimum distance between the hectare on which the dwelling is located and the lake (km, as the crow flies)	-0.0026***	
Lake view: poor, 7 to 100 ha (D)	Specific constant if the lake surface visible (ha) from hectare on which the dwelling is located is 7 to 100 ha	0.0172***	
Lake view: average, 101 to 300 ha (D)	Specific constant if the lake surface visible (ha) from hectare on which the dwelling is located is 101 to 300 ha	0.0477***	
Lake view: good, > 300 ha (D)	Specific constant if the lake surface visible (ha) from hectare on which the dwelling is located is above 300 ha	0.0668***	
Mountain view: average, 3-12 peaks (D)	Specific constant if the number of peaks visible from hectare on which the dwelling is located ranges between 3 and 12	0.0042***	
Mountain view: good ,> 12 peaks (D)	Specific constant if the number of peaks visible from hectare on which the dwelling is located is above 12	0.0163***	
Gradient: 4% - 9% (D)	Specific constant if the land	0.015***	

	gradient is between 4% and 9%		
Gradient: > 9% (D)	Specific constant if the land gradient is above 9%	0.0343***	
Exposure: south-west (D)	Specific constant if hectare on which the dwelling is located is south-west facing	0.009***	
Exposure: north-west, only if canton of Geneva (D)	Specific constant if hectare on which the dwelling is located is north-west facing and located in the canton of Geneva	0.0187***	
Noise: night road traffic (more than 45dB)	Average daily value of nocturnal noise exposure related to road traffic (in dB) for the hectare on which the dwelling is situated	-0.002***	
Noise: daytime rail traffic (more than 50dB)	Average daily value of daytime noise exposure related to rail traffic (in dB) for the hectare on which the dwelling is situated	-0.004***	
Potential accessibility (LOG)	Number of job positions within a maximum distance of 20 km from the hectare on which the dwelling is situated (sum of jobs weighted by 1/distance squared)	0.0547***	
Fiscal capacity (LOG)	Fiscal capacity of municipality (median taxable income)	0.526***	Macro location
Tax rate	Average tax rate in municipality (one-person household, with an income of CHF 50,000, 100,000 or 200,000)	-0.2873***	
Bern (D)	Specific constant related to the city	-0.0433***	
Basel (D)	Specific constant related to the city	-0.0282***	
Lausanne (D)	Specific constant related to the city	-0.1268***	
Geneva (D)	Specific constant related to the city	-0.0791***	
ZH canton outside Zurich (D)	Specific constant related to the canton	-0.0469***	
BE canton outside Bern (D)	Specific constant related to the canton	-0.1105***	
BS canton outside Basel (D)	Specific constant related to the canton	0.0092	
VD canton outside Lausanne (D)	Specific constant related to the canton	-0.1193***	
GE canton outside Geneva (D)	Specific constant related to the canton	-0.0957***	
LU canton (D)	Specific constant related to the canton	-0.1102***	
UR canton (D)	Specific constant related to the canton	-0.1848***	
SZ canton (D)	Specific constant related to the canton	-0.1551***	

OW canton (D)	Specific constant related to the canton	-0.1355***	
NW canton (D)	Specific constant related to the canton	-0.1009***	
GL canton (D)	Specific constant related to the canton	0.1462***	
ZG canton (D)	Specific constant related to the canton	-0.1138***	
FR canton (D)	Specific constant related to the canton	-0.1356***	
SO canton (D)	Specific constant related to the canton	-0.1478***	
BL canton (D)	Specific constant related to the canton	-0.0584***	
SH canton (D)	Specific constant related to the canton	-0.1551***	
AR canton (D)	Specific constant related to the canton	-0.185***	
AI canton (D)	Specific constant related to the canton	-0.1422***	
SG canton (D)	Specific constant related to the canton	-0.1337***	
GR canton (D)	Specific constant related to the canton	-0.0611***	
AG canton (D)	Specific constant related to the canton	-0.1017***	
TG canton (D)	Specific constant related to the canton	-0.1855***	
TI canton (D)	Specific constant related to the canton	-0.1458***	
VS canton (D)	Specific constant related to the canton	-0.2699***	
NE canton (D)	Specific constant related to the canton	-0.2978***	
JU canton (D)	Specific constant related to the canton	-0.2359***	

[1] Significance level of coefficients: * = 10% = 5% **, *** = 1%.

[2] If these variables are included in the estimation for hedonic regression, they are not taken into account in the quality adjustment. Indeed, if they are characteristics of the lease, they cannot be considered as characteristics of the dwelling itself. However, their influence on the level of rent is significant and their omission in estimating hedonic regression could lead to a bias in the other coefficients ("omitted variable bias").

7.3 Impact of hedonic adjustment

	Change, total index (t, t-1)			**Change, AC index (t, t-1)**		
Period	**Unadjusted**	**Adjusted**	**Deviation**	**Unadjusted**	**Adjusted**	**Deviation**
Q1 2011	0.96	0.90	-0.06	1.83	1.41	-0.42
Q2 2011	-0.44	-0.22	0.22	-2.26	-0.73	1.53
Q3 2011	0.04	0.11	0.07	0.38	0.86	0.47
Q4 2011	0.41	0.30	-0.11	2.76	1.99	-0.78
Q1 2012	0.50	0.53	0.04	-0.76	-0.50	0.27

Q2 2012	-0.10	-0.20	-0.10	1.55	0.85	-0.70
Q3 2012	-0.25	-0.10	0.15	-1.05	0.11	1.16
Q4 2012	-0.41	-0.23	0.19	-0.40	1.11	1.50
Q1 2013	0.25	0.21	-0.05	1.60	1.24	-0.37
Q2 2013	0.53	0.39	-0.14	3.27	2.19	-1.08
Q3 2013	0.55	0.48	-0.07	2.98	2.46	-0.52
Q4 2013	0.29	0.29	0.00	0.64	0.64	0.00
Q1 2014	0.02	0.22	0.20	0.21	1.79	1.58
Average	0.18	0.21	0.03	0.81	1.03	0.21
Nb +	9	9	6	9	11	6
Nb-	4	4	7	4	2	7

7.4 Indices by segment (AC and B)

The overall index is constructed as:

$$I^t = \sum_{i=1}^{k} \propto_i I_i^t = \sum_{i=1}^{k} \propto_i \left(\frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} I_{B,i}^t + \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} I_{AC,i}^t \right)$$

Where i = cell, k = number of cells, α_i = weight of the cell, $n_{B,i}^t$ = number of observations in segment B and

$$\tilde{n}_{C,i}^t = \begin{cases} n_{C,i}^t \ , & n_{C,i}^t \ and \ n_{A,i}^{t-1} \geq 3 \\ 0 \ , & n_{C,i}^t \ or \ n_{A,i}^{t-1} < 3 \end{cases}$$

$$\sum_{i=1}^{k} \propto_i = 1$$

It can be broken down accurately into components AC and B:

$$I = \left(\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right) \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\left(\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right)} I_{AC,i}^t + \left(\sum_{i=1}^{k} \propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right) \sum_{i=1}^{k} \frac{\propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\left(\sum_{i=1}^{k} \propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right)} I_{B,i}^t$$

Where $\left(\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right) + \left(\sum_{i=1}^{k} \propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right)$, $\sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\left(\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right)}$, $\sum_{i=1}^{k} \frac{\propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\left(\sum_{i=1}^{k} \propto_i \frac{n_{B,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t} \right)} = 1$

7.5 Breakdown of the adjustment factor

7.5.1 Breakdown at cell level

The adjustment factor is defined as $\hat{g}_{C,i}^t = \frac{\left(\prod_{j=1}^{n_{C,i}^{*t}} \hat{y}_{j,t,2003}{}^{p_{j,t}} \right)^{\frac{1}{\sum_j p_{j,t}}}}{\left(\prod_{k=1}^{n_{A,i}^{*t-1}} \hat{y}_{k,t-1,2003}{}^{p_{k,t-1}} \right)^{\frac{1}{\sum_k p_{k,t-1}}}}$. It can be broken down into its various components by integrating the relationship $\hat{y} = \tilde{\alpha} e^{\beta_1 X_1} X_2{}^{\beta_2}$. The average estimated rent within a cell (here component C) corresponds to:

$$\prod_{j=1}^{n_{C,i}^{*t}} \hat{y}_{j,t,2003}^{\frac{p_{j,t}}{\sum_j p_{j,t}}} = \prod_{j=1}^{n_{C,i}^{*t}} \left(\tilde{\alpha} e^{\beta_1 X_{1,t}^j} X_{2,t}^{j\ \beta_2}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}} = \tilde{\alpha} \prod_{j=1}^{n_{C,i}^{*t}} \left(e^{\beta_1 X_{1,t}^j}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}} \prod_{i=1}^{n_{C,i}^{*t}} \left(X_{2,t}^{j\ \beta_2}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}}$$

The adjustment factor corresponding to the relationship of estimated mean rents for segments C and A , it can be rewritten:

$$\hat{g}_{C,i}^t = \frac{\tilde{\alpha} \prod_{j=1}^{n_{C,i}^{*t}} \left(e^{\beta_1 X_{1,t}^j}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}} \prod_{i=1}^{n_{C,i}^{*t}} \left(X_{2,t}^{j\ \beta_2}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}}}{\tilde{\alpha} \prod_{k=1}^{n_{A,i}^{*t-1}} \left(e^{\beta_1 X_{1,t-1}^k}\right)^{\frac{p_{k,t-1}}{\sum_k p_{k,t-1}}} \prod_{k=1}^{n_{A,i}^{*t-1}} \left(X_{2,t-1}^{k\ \beta_2}\right)^{\frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}$$

$$= \frac{\prod_{j=1}^{n_{C,i}^{*t}} \left(e^{\beta_1 X_{1,t}^j}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} \left(e^{\beta_1 X_{1,t}^k}\right)^{\frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}} \cdot \frac{\prod_{i=1}^{n_{C,i}^{*t}} \left(X_{2,t}^{j\ \beta_2}\right)^{\frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} \left(X_{2,t-1}^{k\ \beta_2}\right)^{\frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}$$

$$= \underbrace{\left[\frac{\prod_{j=1}^{n_{C,i}^{*t}} e^{X_{1,t}^j \frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} e^{X_{1,t-1}^k \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}\right]^{\beta_1}}_{Factor\ related\ to\ X_1} \cdot \underbrace{\left[\frac{\prod_{j=1}^{n_{C,i}^{*t}} X_{2,t}^{j\ \frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{n_{A,i}^{*t-1}} X_{2,t-1}^{k\ \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}\right]^{\beta_2}}_{Factor\ related\ to\ X_2}$$

Dummy variable

If the variable X_1 is a dummy and *a* observations assume the value of 1 at t *(b* observations at t-1), the factor is:

$$\left[\frac{\prod_{j=1}^{a} e^{\frac{p_{j,t}}{\sum_j p_{j,t}}}}{\prod_{k=1}^{b} e^{\frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}\right]^{\beta_1} = \left[\frac{e^{\sum_{j=1}^{a} \frac{p_{j,t}}{\sum_j p_{j,t}}}}{e^{\sum_{k=1}^{b} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}}}\right]^{\beta_1} = e^{\beta_1 \left(\sum_{j=1}^{a} \frac{p_{j,t}}{\sum_j p_{j,t}} - \sum_{k=1}^{b} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}\right)}$$

with $0 \leq \sum_{j=1}^{a} \frac{p_{j,t}}{\sum_j p_{j,t}}, \sum_{k=1}^{b} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}} \leq 1,$

$\sum_{j=1}^{a} \frac{p_{j,t}}{\sum_j p_{j,t}}, \sum_{k=1}^{b} \frac{p_{k,t-1}}{\sum_k p_{k,t-1}}$ represent proportions of observations satisfying the condition of the X_1 variable in periods t and t-1, taking into account their respective survey weights.

7.5.2 Aggregation of breakdown

Each component of the adjustment can be roughly aggregated to be considered from a broad standpoint. The development of this aggregation is presented here.

Representation is simplified into three factors: $\frac{1}{g_{C,i}} = \frac{1}{g_{C,i}^1} \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3}$

Thus $I_{AC}^t = \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{AC,i}^t = \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_{C,i}^1} \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3}$

The target, for the g1 factor, is to obtain $\overline{g_C^1}$ such that: $I_{AC}^t = \frac{1}{\overline{g_C^1}} \cdot \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3}$

=> $\frac{1}{\overline{g_C^1}} \cdot \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3} = \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \frac{1}{g_{C,i}^1} \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3}$

Limitations and impact of hedonic adjustment for the rent index

$$\frac{1}{g_C^1} = \underbrace{\frac{1}{\sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_i^2} \cdot \frac{1}{g_i^3}} \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3}}_{*} \cdot \frac{1}{g_{C,i}^1}$$

$\frac{1}{g_C^1}$ is thus a weighted average of factors $\frac{1}{g_{C,i}^1}$, where the weighting (*) combines unadjusted indices corrected for other factors (g2, g3), cell weights ($\propto_i$) and the proportion of AC in the cell ($\frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}$).
The line of reasoning is similar as for other factors, but the definition of other factors should be adapted (g1 and g3 for g2, g1 and g2 for g3). However, multiplication of these aggregated factors does not result precisely in the adjusted index:

$$\sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t \cdot \frac{1}{g_{C,i}^1} \cdot \frac{1}{g_{C,i}^2} \cdot \frac{1}{g_{C,i}^3} \neq \frac{1}{\overline{g_{C,\iota}^1}} \cdot \frac{1}{\overline{g_{C,\iota}^2}} \cdot \frac{1}{\overline{g_{C,\iota}^3}} \cdot \sum_{i=1}^{k} \frac{\propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}}{\sum_{i=1}^{k} \propto_i \frac{\tilde{n}_{C,i}^t}{n_{B,i}^t + \tilde{n}_{C,i}^t}} I_{unadj,AC,i}^t$$

They should be viewed as approximations.

7.5.3 Primary values

	Factors						
Period	**Age**	**Log (m2/room)**	**Storey**	**Garage**	**Duplex**	**Penthouse**	**Location**
Q1 2011	1.0031	1.0000	1.0004	0.9997	0.9992	0.9974	1.0048
Q2 2011	0.9999	0.9966	0.9996	1.0012	0.9991	0.9984	0.9895
Q3 2011	1.0020	0.9980	1.0004	1.0023	0.9998	1.0005	0.9933
Q4 2011	1.0047	0.9977	1.0008	0.9983	0.9998	0.9991	1.0071
Q1 2012	1.0056	0.9987	1.0004	1.0005	0.9998	1.0001	0.9932
Q2 2012	1.0003	0.9957	1.0008	0.9998	0.9999	1.0008	1.0108
Q3 2012	1.0014	0.9925	1.0007	0.9997	0.9983	1.0011	0.9951
Q4 2012	1.0015	0.9999	1.0006	0.9973	1.0009	0.9971	0.9875
Q1 2013	1.0108	0.9986	1.0007	1.0003	1.0004	0.9998	0.9932
Q2 2013	1.0046	1.0047	1.0000	1.0001	1.0014	1.0014	0.9989
Q3 2013	1.0040	1.0043	0.9997	1.0003	1.0007	0.9992	0.9968
Q4 2013	1.0026	1.0057	0.9997	1.0008	1.0004	1.0015	0.9895
Q1 2014	1.0005	1.0026	1.0003	1.0001	1.0003	0.9982	0.9828
Average	1.0032	0.9996	1.0003	1.0000	1.0000	0.9996	0.9956
Standard dev	0.0028	0.0037	0.0004	0.0012	0.0008	0.0014	0.0078
Min	0.9999	0.9925	0.9996	0.9973	0.9983	0.9971	0.9828
Max	1.0108	1.0057	1.0008	1.0023	1.0014	1.0015	1.0108
Nb +	12	5	10	8	6	6	3
Nb-	1	8	3	5	7	7	10