Estimating hospital inflation from routinely collected DRG data: Application to Swiss Hospitals

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1 Introduction

In many industrialized countries the financing of the hospital industry has been evolving towards a prospective payment system where hospitals are paid a fixed fee for each patient in a certain diagnostic category. In Switzerland, studies for the implementation of such a system are currently under way. The shift to prospective payment systems based on patients categorized according to their diagnostics and the procedures they underwent is in accordance with many health economists' belief that the relevant unit of analysis for pricing decisions is the cost of a treatment episode. Accordingly, the study of prices and their evolution in the hospital sector and of the health care sector at large should be based on the same concept of output. This contrasts with the concepts currently underlying the construction of health care price indices. In particular the health care component of the Swiss consumer price index is based on the prices of inputs to the production of medical services and not on the concept of output just described. At the producer level, there does not exist today in Switzerland a price index for the hospital sector. Such a producer price index, which takes as a starting point the same concept of output used in prospective payment systems, would be the relevant one to consider for the purpose of studying the evolution of prices in the hospital sector and in particular for updating fees paid to hospitals.

The objective of this research paper is to study and propose a methodology for measuring hospital inflation from routinely collected DRG data in order to enable the State government to adjust the prospective payment system per DRG by the hospital inflation rate. The inflation measure investigated will have as a guiding principle the "treatment of a case" as typified by the classification of diagnostics and procedures into AP-DRGs .(All Patient Diagnostic Related Groups), taking into consideration the prospective payment system which is currently being studied for potential implementation in Switzerland.

In the second section, we deal with the issues relevant to the construction of a health care price index. We then present the Swiss hospital DRG system and our dataset. In section 4, we detail how we estimate hospital inflation rate from DRG data using regression methods. In section 5, we take this a step further by describing a sequential procedure to the calculation of a hospital PPI that can be made to mimic the regression calculations. And finally we will discuss our results.

2 Issues - price indices

2.1 Price indices in the health care sector

The health care industry presents, in the opinion of some authors (Triplett 2000), the same challenges as other service industries albeit on a larger scale. The major measurement problem presented by the construction of price and quantity indices in service industries and in particular in the health care sector arises from the fact that in most cases it is not clear what is being transacted, what the correct definition of output is and to what services correspond the prices being paid (Griliches 1992). Further, in the health care sector, the "correct" concept of output is even harder to establish.

Associated with the problem of defining the output is the one of determining changes in the quality of what is being produced. If a new treatment for a certain disease becomes available at the same price as the old treatment but is much more effective in delivering the desired outcome then one should consider that there was an effective price decrease if our concept of output is the "outcome of a treatment".

We briefly describe each of these aspects in turn.

2.1.1 Concept of output

In the mid 1960's Scitovsky (1964, 1967) proposed the relevant output to be priced as an illness episode. This was in opposition to the implicit output definition which was obtained by deflating the national accounts of the health care sector by a health sector deflator calculated based on the prices of items such as a hospital room rate, a visit to a doctor, the price of a frequently prescribed medicine, etc (see for example Berndt, Cutler, Frank, Griliches, Newhouse and Triplett (2001)). It is well known that the measurement of input prices in a production process is a poor proxy for the evolution of the prices of the output, especially in sectors where there is substantial technological progress such as in the health care sector. Nevertheless Scitovsky's initial proposal was followed only much later by work of other authors such as Cutler et al (1998) who estimated the price of treating heart attacks, Shapiro and Wilcox (1996) who estimated the price of cataract surgery and Berndt, Busch and Frank (2001) who studied the cost of the treatment of depression. These studies show that there can be substantial differences in the evolution of prices once technological/quality factors are taken into account.

2.1.2 The treatment of quality changes

In a classical study Griliches (1967, 1971) addresses the consequences of not accounting for quality changes in the automobile industry using a methodology now known as hedonic pricing. Griliches (1967, 1971) and Rosen (1974) provided the basic hedonic pricing framework. In summary, prices are regressed against the product characteristics and the price to be used in the price index is the price of an homogeneous product, that is, once influences of different characteristics on prices have been removed. Under certain conditions, namely competitive markets, the regression coefficients on the product characteristics reflect consumer valuations of the different characteristics, hence providing an economic theoretical framework for the construction of the price of an artificial homogeneous good.

It is well known that health care markets are far from satisfying the conditions of competitive markets. Nevertheless in the hospital context and for the purpose of constructing a production index that reflects the evolution of costs applying the same methodology reflects only the more limited and implicit assumptions that hospitals minimize costs and that they don't have market power in the markets for the inputs they use. One is not attempting to measure the consumers valuation for the services provided as in a consumers cost-of-living index where consumer prices reflect these valuations under market conditions In the health care sector the application of the hedonic approach to heath care prices in the context of cost-of-living indices has been discussed at length in Berndt et al (2001). For the specific case of pharmaceuticals Griliches and Cockburn (1994) and Jacobzonne et. al. (1997) are examples. There is also a strand of literature in which particular diseases are studied. Here the effectiveness of a treatment is taken into account and the decrease (increase) in the cost of treating a certain disease that results from the use of different technologies is corrected for any observable change in the outcome. The work of Cutler et al (1998), Shapiro and Wilcox (1996) and Frank, Berndt and Busch (2001) are examples of this approach as is the more recent work of Chevrou-Severac, Jeanrenaud and Wasserfallen (2003) on the costs of heart disease.

2.2 Current practice in price index construction in the health care sector

2.2.1 The American medical price indices

The American consumer price index (CPI) and producer price index (PPI) have very different heritages and consequently take distinct approaches to measuring health care sector prices. The hospital component of the CPI has as item components the prices of inpatient and outpatient hospital services measured per stay in hospital (independent of the number of days of the stay), and other input prices such as the price of x-rays, laboratory tests etc.. Only about 6% of the quotes obtained for the CPI are based on Diagnostic Related Groups (DRGs), that is, on items that pertain to the treatment of certain illnesses as opposed to items that refer to the inputs in treating those illnesses (Berndt et al 2001).

The medical PPI is much more recent that the CPI. The Bureau of Labor statistics (BLS) has only published a PPI for the health sector since December 1992, the base period. The hospital services PPI attempts to measure the net price paid to hospitals for the entire bundle of services received during a hospital stay. The sampling unit within the hospital is a patient bill classified by its DRG. The concept of output adopted is that of the cost of an episode of illness (see Appendix 1 for more details). Furthermore, the hospital PPI includes corrections for changes in the average length of stay. A decrease in the average length of stay for the treatment of a certain condition is considered as a quality change and not as a reduction in cost (Berndt et al 2001 and Catron & Murphy (1996)).

2.2.2 The Swiss medical price indices

Currently the Swiss Federal Statistical Office (OFS) does not produce a producer price index for the medical sector. The Swiss CPI contains a hospital service component. The principles underlying the construction of the hospital services component of the CPI are similar to the American counterpart. Quotes are obtained from hospitals regarding average prices of a day in the hospital and prices of items which can be regarded as inputs in the production of health care such as laboratory tests, x-rays, physiotherapy, etc. It is therefore the perspective of inputs to healthcare provision principle that is adopted and not the cost-of-illness perspective (see appendix 2 for more details).

There is however an important difference between the American and Swiss hospital components of the CPI. What is priced in the American index (since 1997 but not previously) is the stay in the hospital and not the day in the hospital. The change in methodology in the American index was due to changes in the case mix of patients in hospitals over time, and in particular to the increase in average severity of patients due to shifts of patients from inpatient to outpatient treatment. This led to an increase in the index when the item considered was price per day but this did not correspond to an effective increase in price but only to a shift in the composition of the hospital population. The Swiss index prices the day in hospital and is therefore more sensitive to shifts in hospital case mix and case severity mix.

3 The Swiss hospital system

3.1 The Swiss hospital DRGs and costs

Currently in Switzerland there are studies under way for the implementation of a prospective payment system in the hospital sector. This means that hospitals will be paid a fixed price per patient depending only on the classification of that patient into a diagnostic group. The main classification methodology being considered in Switzerland is that of APDRG's (All Patient Diagnostic Related Groups). This is in accordance with many health economists' belief that the relevant unit of analysis for pricing decisions is the cost of a treatment episode. The main reason for this is that technological progress tends to vary widely from disease to disease. It seems appropriate therefore to study the evolution of prices and costs in the medical care sector on diseases by diseases basis or for a certain chosen panel of diseases and treatments and not the evolution of prices of factors that enter in the production of health care services. Furthermore from the perspective of updating payments made to hospitals in the prospective payment system, the relevant inflation is the one measured on the cost of a treatment episode, which is the unit of payment for the hospital. Also different hospitals are likely to face different inflation rates merely due to the composition of their patient population. The inflation rate numbers for the United States calculated using the producer price index for the hospital sector are exhibited in table 1. The table shows how widely prices can vary from one disease group to another.

Table 1 : US Hospital PPI by Major Diagnostic Categories

Disease Group / Year	*2000*	*2001*	*2002*
General medical and surgical hospitals	2.7%	3.0%	3.6%
Diseases and disorders of the nervous system	3.1%	2.5%	2.5%
Diseases and disorders of the ear, nose, mouth, and throat	3.6%	-0.2%	6.4%
Diseases and disorders of the respiratory system	2.5%	2.8%	4.4%
Diseases and disorders of the circulatory system	3.0%	2.8%	4.2%
Diseases and disorders of the digestive system	4.2%	3.1%	6.1%
Diseases and disorders of the hepatobiliary system and pancreas	2.5%	3.4%	5.9%
Diseases and disorders of the musculoskeletal system and connective tissue	2.4%	6.0%	4.0%
Diseases and disorders of the skin, subcutaneous tissue and breast	3.6%	4.5%	4.8%
Endocrine, nutritional, and metabolic diseases and disorders	3.6%	3.0%	3.9%
Diseases and disorders of the kidney and urinary tract	5.2%	6.1%	12.1%
Diseases and disorders of the male reproductive system	1.6%	15.1%	3.0%
Diseases and disorders of the female reproductive system	2.7%	4.3%	9.2%
Pregnancy, childbirth, and the puerperium	3.4%	6.2%	3.8%
Newborns and other neonates with conditions originating in the perinatal period	4.3%	1.8%	10.5%
Diseases and disorders of the blood and blood forming organs and immun. diseases	2.6%	2.4%	9.3%
Myeloproliferative diseases and disorders, and poorly differentiated neoplasms	4.8%	4.4%	4.0%
Infectious and parasitic diseases (systemic or unspecified sites)	4.3%	2.8%	4.3%
Alcohol/drug use and alcohol/drug induced organic mental disorders	10.3%	3.2%	5.5%
Injuries, poisonings, and toxic effects of drugs	4.7%	4.1%	7.4%
Factors influencing health status and other contacts with health services	3.2%	3.0%	4.8%

Source: US BLS, Producer Price Index

3.2 Data Available

The Swiss prospective payment system by AP-DRG

The DRGs (Diagnostic Related Groups) constitute a system of patient classification based on primary and secondary diagnoses and procedures, age and length of stay. These groups are defined such that each category has a more or less a uniform cost. Therefore, treating a patient in any given DRG can be considered as a single medical service with regards to costs. The DRG system was first developed in the early 80s in the US. In Switzerland, a similar classification system, Swiss APDRG, has been developed since 1994. This system, administered by the Swiss Institute of Health and Economics (ISE), is used as a basis for cost reimbursement of hospitals in Switzerland. The DRG-adjusted number of cases is one of the best available simple measures of output. In any case it is more representative of costs than the number of patient-days. In 2006, one hospital out of two will be financed using the AP-DRGs prospective payment system. Under this payment system, hospitals will be paid by DRGs recorded, prospectively, i.e. on the basis of the previous year's activity. As a consequence, the payments by DRG given by the Cantonal health partners should be adjusted by an inflation rate, hence the importance of estimating an appropriate rate.

The SwissDRG dataset[1]

The data available for this work is the discharge data from 4 hospitals from 2000 to 2002 (see table 3). The data consist of patient level records containing demographic information for the patient and the patient AP-DRG code as well as detailed diagnostic and procedures

[1] We thank the ISE institute for making this dataset available to our research.

information, the length of stay of the patient in the hospital and the cost of the stay. The costs per AP-DRG do not include investment charges, research or teaching.

Table 2 – Episodes of care per Hospital

Hospital	**2000**	**2001**	**2002**	***Total***
University hospital	18’039	17’871	17’783	***53’693***
Regional hospital 1	8’937	8’373	8’558	***25’868***
Regional hospital 2	3’964	3’841	3’931	***11’736***
Regional hospital 3	5’402	5’245	5’433	***16’080***
Sub-total for the 3 regional hospitals	*18’303*	*17’459*	*17’922*	***53’684***
Total	***36’342***	***35’330***	***35’705***	***107’377***

Note: The 3 regional hospitals belong to the same canton.

The university hospital is located in one canton (canton A), and the 3 regional hospitals in another canton (canton B). The 3 regional hospitals are comparable to the University hospital in terms of the number of patients treated for the three years. However, they do not necessarily treat the same pathologies, so they do not have the same DRG distribution. The table below summarizes the number of DRGs and the average length of stay in each hospital.

Table 3: number of DRGs and average LOS by hospital

Hospital	***Number of AP-DRGs***	***Average length of stay***
University hospital	460	8.56 days
Regional hospital 1	438	8.15 days
Regional hospital 2	406	7.69 days
Regional hospital 3	427	7.67 days

So as to obtain a homogeneous dataset, only AP-DRGs in which the minimal number of hospital stays registered was at least 30 across all hospitals have been used. Only DRGs that are recorded each year have been included[2]. In view to compute hospital inflation, we have only worked on the inliers hospital stays, that are the stays whose length is comprised between two bounds (in terms of number of days at hospital) defined by the AP-DRGs Swiss system. The bounds for the length of stay are available DRG by DRG. About 5% of the cases are defined as outliers. Outliers’ stays are not reimbursed on the same basis as inliers stays. For this kind of stays the reimbursement is modified relating to the length of the stay. So computing the inflation rate on inliers stays only is relevant because inliers stays are used as benchmark hospital stays to compute the value of points that finances the hospital DRGs stays through Cost-Weights.

[2] We have dropped the DRGs 469 and 477.

4 Estimating hospital inflation rates

4.1 Method of investigation

We will use panel data methods and the information obtained from the reviews mentioned above to analyze the evolution of hospital costs. In particular we will study models of the type:

$$y_{nit} = \alpha_i + \delta_t + x_{nit}\beta_i + \varepsilon_{nit}$$

where y_{nit} is the logarithm of the cost of the stay of patient n in DRG group i in period t, α_i is an average cost by DRG, δ_t is the average difference in the cost (log of) between the base period and period t, x_{nit} are patient characteristics such as age, degree of severity of disease, length of stay in the hospital, etc. and ε_{nit} is a perturbation term. The hospital PPI is retrieved from the estimated value of δ_t.

Method of estimation

The specific control variables to include in the model will depend on the type of disease group as well as on consideration of the desired meaning of the final index. In particular, including length of stay as a control variable implies that one considers decreases in the average length of stay as a change in the quality/technology of delivering a treatment, so any decrease in cost associated with a decrease in the length of stay is not reflected in the price index.

The fixed effect (FE) specification implicitly assumes that patients (for the purpose of calculating the cost of their stay) differ only in the DRG they have been classified into and in the length of their stay. After these effects have been removed patients are considered homogeneous from the point of view of their cost.

Estimation proceeds by OLS. As the number of coefficients is very large (reaching close to 1000) we use an iterative backfitting procedure which reduces significantly the memory requirements as well as computation time.

In this set-up the inflation rate from period $t-1$ to period t is given by $\exp\left(\delta_t - \delta_{t-1}\right) - 1 \cong \delta_t - \delta_{t-1}$.

The use of the cost variable in log form requires further explanation. It is commonly observed that costs per case have highly skewed distributions with a small number of very large outliers, which is to say that the distribution of ε_{nit} if one considers the cost variable in levels will be far from a normal distribution. The transformation of levels into logarithms has the objective of making the transformed variable closer to a normal and hence the OLS estimates based on the transformed variable will be efficient. This type of transformation, usually referred to as variance stabilizing transformations, has a long history in statistics (see for example Barttlet (1947), Box & Cox (1964,1982), Bickel & Doksum (1981) and Hinkley & Runger (1984)). It amounts to a change of scale so that in the new scale our model has desirable properties, i.e. the properties that make OLS optimal in some sense. Another issue of relevance is the interpretation of the coefficients on this transformed scale. With the logarithmic transformation our coefficients are easily interpretable but this does not mean the logarithm is the appropriate scale. An alternative approach is to follow Holly and Pentsak (2004), which instead develop estimation procedures based on maximum likelihood that take into account the skewness and kurtosis of the observed variable and where there is no need for transforming the dependent variable. We leave the extension of this work to the latter methods for future study.

Weighting costs data

As we aim to construct a hospital price index, in the spirit of price index theory, we will use weights so that our regression procedures replicate as closely as possible known indices. In Laspeyres price index, the quantity is fixed to the one observed in the baseline period. Here an observation of DRG i in year t will have a weight equal to the share of that DRG's costs on total costs in the baseline year (2000) divided by the number of inpatient days for DRG i in year t. As a consequence, in a given year, the sum of the weights for the observations of a certain DRG will always be equal to that DRG's share of total cost in the baseline year. We present a formal justification and further discussion of this choice of weights in Appendix 3. Alternatively one could sample patients in DRG's with probability equal to the weights just defined.

4.2 Results: hospital inflation rates

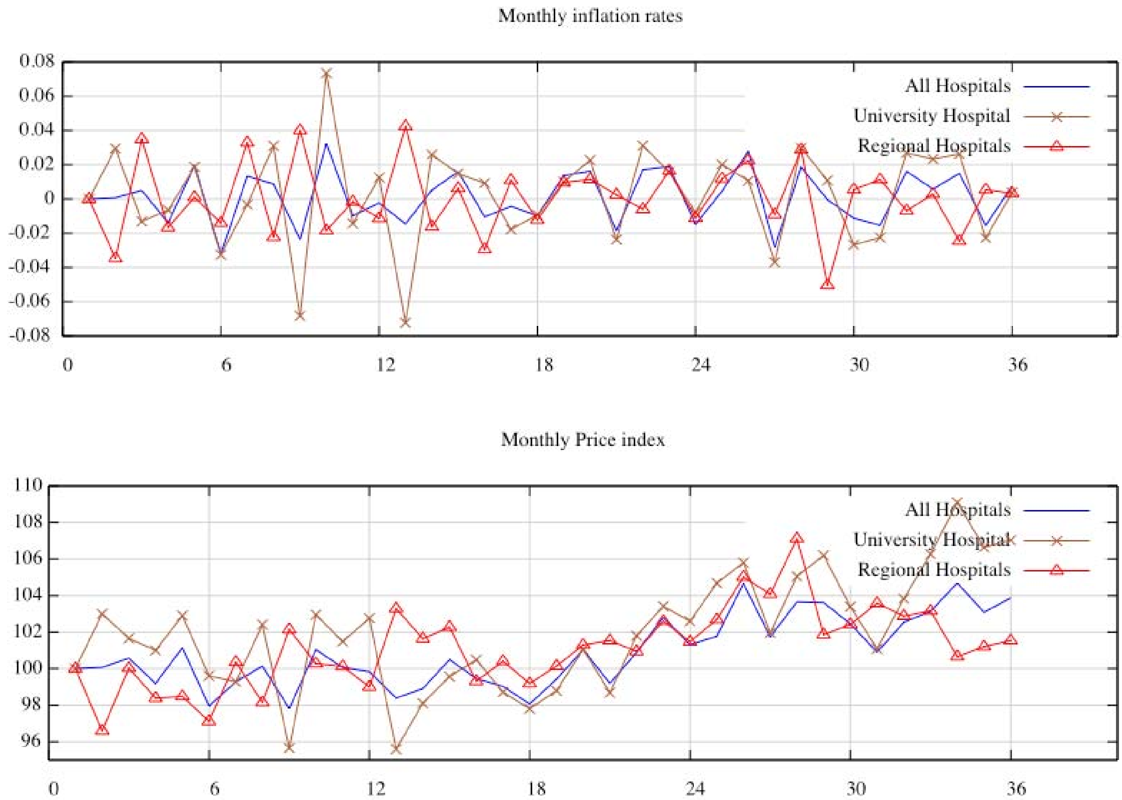
We have estimated different price indices and inflation rates. We have computed monthly inflation rates for all the hospitals together, then for the hospitals within cantons A and B respectively. We have then controlled for the higher DRG costs of the university hospital by introducing a dummy variable for this hospital when computing overall inflation. The effect of the length of stay on the cost of hospitalization is then withdrawn by introducing the LOS in our estimation. Thus, the inflation rate computed is controlled for the impact of changing length of stays on hospital costs. Following, as the costs are registered and distributed to patient stays according to hospital activities once a year, we have also computed an annual inflation rate that we can compare directly with the Swiss hospital inflation. Finally we have also provided PPI by Major Diagnostics Categories (MDC).

It is important here to make several remarks concerning the monthly inflation estimates reported below:

- the accounting procedures in hospitals mean that a significant portion of the cost of a patient in a certain DRG is obtained only at the end of the year after cost accounting procedures determine the amount of fixed costs. Hence monthly variation within a year can be a reflection of accounting practices;
- our sample consists of only 4 hospitals and is meant as illustrative - an interpretation of a Swiss price index should be given if one could have a representative sample of patients from all hospitals - but it is nevertheless enough to show that there can be significant and disparate inflation for different hospitals and that this inflation can be very different from the hospital component in the Swiss CPI;
- the excessive monthly variation found is most of the times not statistically significant and should not be interpreted as real price variation;
- there is however a significant shift from one year to the next and this can be rightly considered as a change in the price level;
- monthly estimates are relevant in practice if one could obtain real time information of patient costs, which is not the case for the present sample where monthly costs are obtained ex-post, at the end of the year, for each hospital. It is nevertheless relevant from an illustrative point of view, to show how the methodologies discussed can be applied to an extended period of time

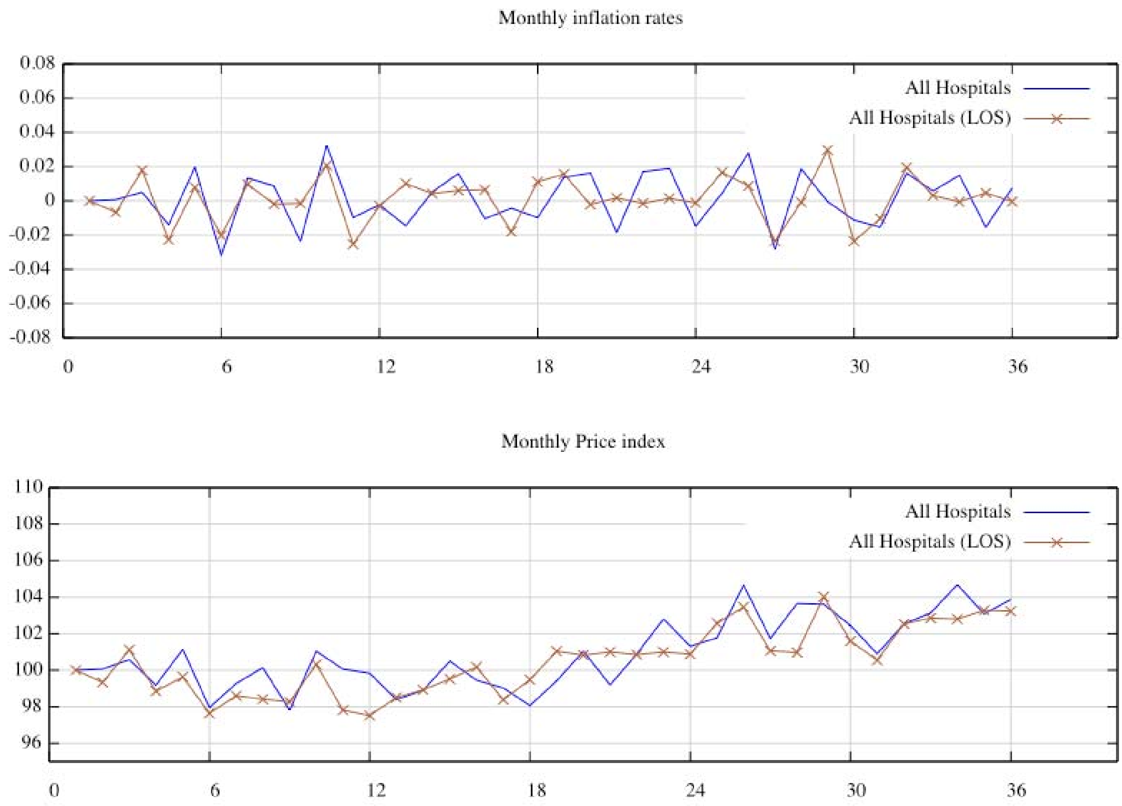
With the previous comments in mind we turn to the discussion of our findings.

Figure 1: Monthly inflation rates and price indices from January 2000 to December 2002



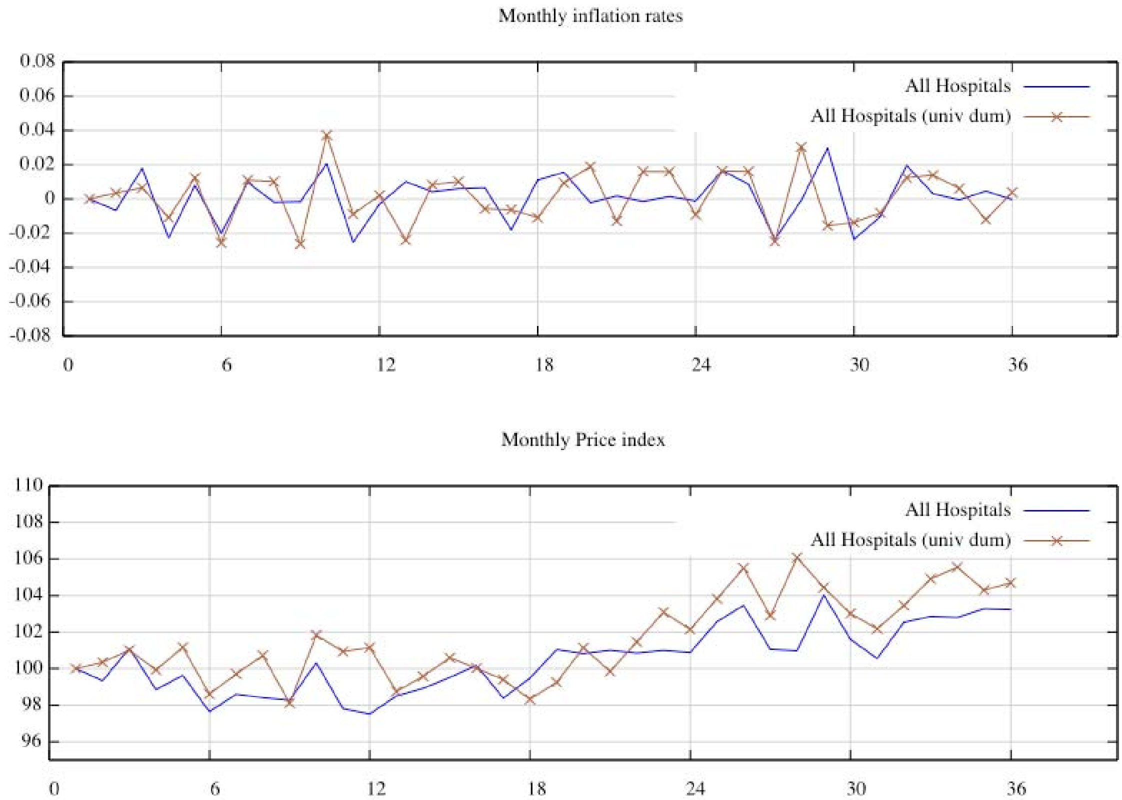
The monthly inflation rates range from –3.2% to 3.3%, with a major contribution of the University hospital to the extremes. Although monthly variation is permanent throughout the period we observe a clear shift in the index in the last year.

Figure 2: Monthly inflation rates and price indices with and without LOS adjustment (2000-2002)



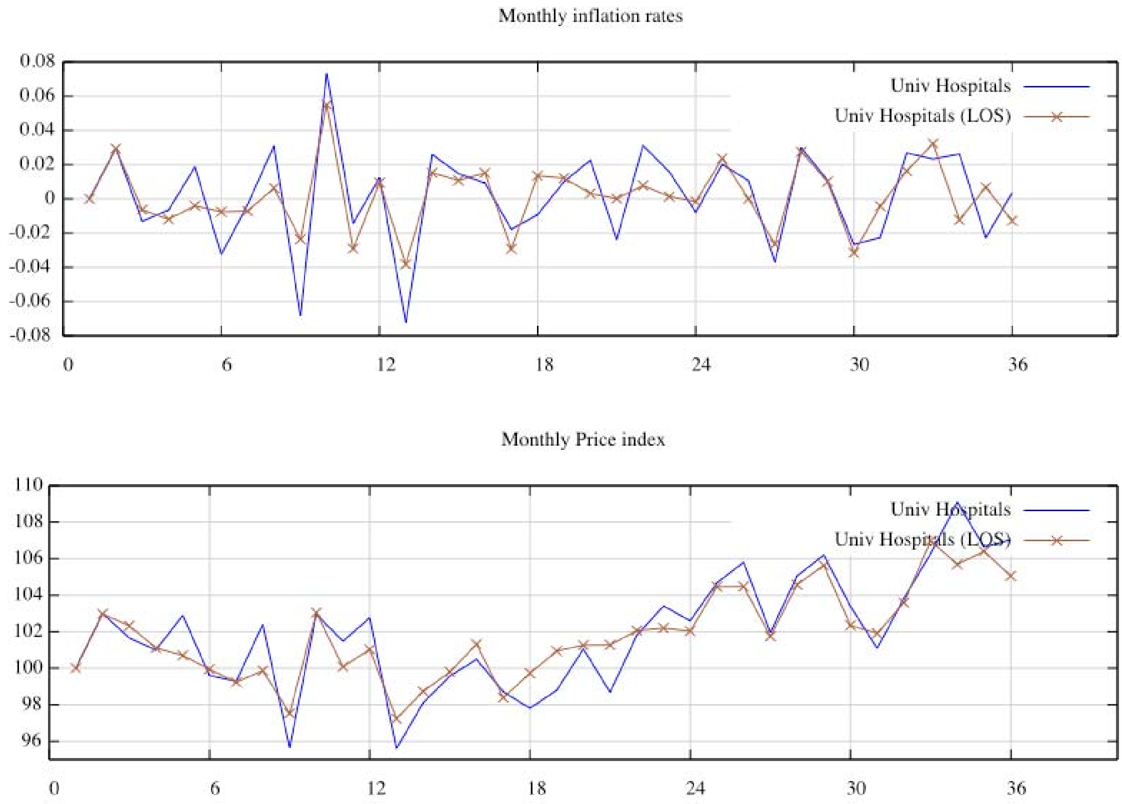
Accounting for the effect of length of stay on hospital costs has little impact on the monthly inflation rates and price levels, although below we note theat at the year level the are differences when comparing the different types of hospitals.

Figure 3: Monthly inflation and price indices, with and without university hospital impact control



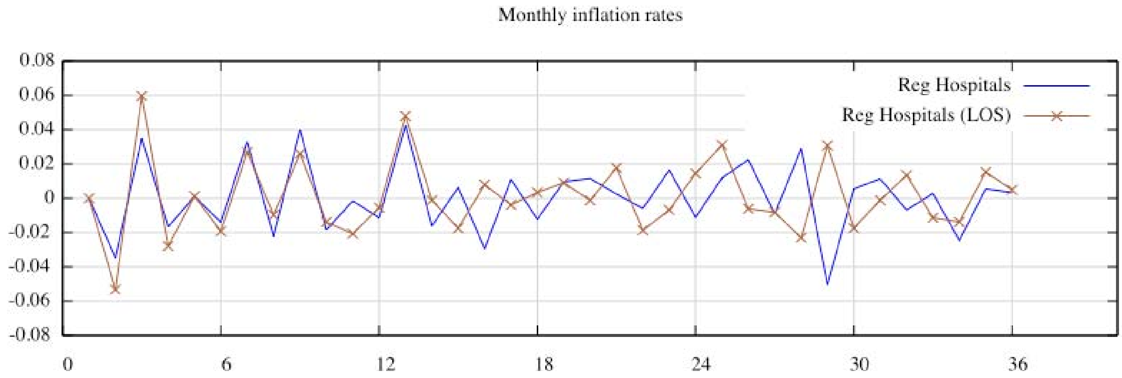
When accounting for the impact of the university hospital on the DRG costs, the hospital PPI is higher at the end of the time period (for the year 2002).

Figure 4: Monthly inflation and price indices for University hospital



In general and as expected, removing the effect of LOS tends to smooth the variations in the monthly inflation rates. For the case of the university hospital this occurs mainly in the first year of observations. There is also a clear upward trend in the price index for the university hospital in the last year.

Figure 5: Monthly inflation and price indices for the three regional hospitals



From 2000 to 2002, the inflation measure for the three regional hospitals oscillates significantly more in the first year than in subsequent years. There is also a clear upward trend in the price level over the period under consideration.

As pointed out earlier the monthly estimates of inflation are quite variable, but most of these oscillations just reflects the fact that estimates are not precise and hence many of them are not statistically different from zero, So one should not consider this variation as an underlying variation in costs. Nevertheless there in an upward trend in the price index which is quite noticeable in all the scenarios considered and is more appropriately described by inflation rates computed on an annual basis to which we now turn.

Table 4: Annual inflation rates

All DRGs	2001	2002	LOS model 2001	LOS model 2002
All hospitals	0.16%	3.02%	1.08%	2.32%
University hospital (canton A)	-1.29%	5.21%	-0.22%	3.84%
3 regional hospitals (canton B)	1.96%	1.84%	2.64%	2.06%
All hospitals With university hospital dummy	0.01%	3.83%	0.93%	3.13%
Swiss Health CPI[3]	*0.6%*	*0.4%*		
Swiss hospital CPI[4]	***0.7%***	***1.7%***		

Concerning the overall inflation rate, there is barely any change in prices in 2001 (0.16%) and a positive inflation rate about 3% in 2002. The Swiss hospital CPI also points to a zero inflation in 2001 but is below our computed inflation by 1.5% in 2002. The University hospital has a general level of costs that is lower in 2001 when compared with 2000 and a significant higher one in 2002. This wide variation of inflation from 2001 to 2002 comes from changing accounting principles used in the University hospital during the period. Taking a closer look at changes in the budget of the university hospital between 2001 and 2002 we notice that two factors were responsible for the growth in production costs up. In 2002, a new Cantonal Law on public employees and the reclassification of medical staff increased costs by about 2.5%. Also the application of a new Federal Law on therapeutic products pushed costs up by about 1%. In the three regional hospitals the costs grew steadily over the period considered. Estimated inflation is about 2% in 2001 and 1.8% in 2002. We again have a divergence with inflation measured in the hospital CPI in 2001.

When accounting for the impact of the length of hospital stays on hospital costs, the inflation rate is higher in 2001 (1.1%), and smaller in 2002 (3.8%). Taking into account of the impact of the length of hospital stay on DRG costs reveals that the cost decrease in university hospitals (in 2001) was mostly caused by a decrease in the length of stay[5]. This effect is also visible in regional hospitals where inflation is higher when changes in length of stay are taken into account.

We have also taken into account the fact that the university hospital has potentially higher hospital costs than the regional hospitals for two main reasons:

- it provides a wider range of medical treatments than regional hospitals (such as treatments for burned patients, cardiac transplants), and
- by law, the university hospital is in charge of training and medical research, activities that increase its production cost. Even if costs per DRG should not take into account such activities, the method of accounting for medical research and training has only become more precise in 2003.

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[3] Source : OFS (Federal Statistical Office), baseline: 100 Swiss francs in 2000.
[4] The hospital CPI contains health care items from stationary AND ambulatory hospital admissions.
[5] Which decreased 1.4% on average from 2000 to 2001 for all hospitals and 2.1% from 2001 to 2002 in the regional hospitals only.

In order to take into account higher production costs of the university hospital, we have introduced in our model a dummy variable for all the hospital stays recorded at the university hospital. This variable is highly significant indicating that the level of costs in the university hospital is higher. However the impact on inflation is negligible..

Following the BLS, we have computed Swiss hospital producer price indices by Major Diagnostic Categories (see table 5, below). As expected, the inflation rates are quite different from one MDC to another, as well as when compared to the general hospital inflation, and to the Swiss hospital CPI.

Table 5: Swiss hospital inflation by Major Diagnostic Categories (MDC)

Disease group - Major Diagnostic Categories	Base model		LOS model	
	2001	*2002*	*2001*	*2002*
1-Diseases and disorders of the nervous system	-2.49%	0.90%	-1.02%	-0.28%
2-Diseases and disorders of the eye	-0.49%	19.91%	0.08%	19.01%
3-Diseases and disorders of the ear, nose, mouth, and throat	1.82%	0.60%	3.55%	0.31%
4-Diseases and disorders of the respiratory system	-0.41%	1.60%	-0.73%	1.54%
5-Diseases and disorders of the circulatory system	5.00%	0.02%	4.48%	-0.85%
6-Diseases and disorders of the digestive system	-0.12%	2.93%	2.22%	2.70%
7-Diseases and disorders of the hepatobiliary system and pancreas	-3.02%	1.70%	1.40%	-0.22%
8-Diseases and disorders of the musculoskeletal system and connective tissue	-2.87%	4.17%	-1.26%	3.97%
9-Diseases and disorders of the skin, subcutaneous tissue and breast	-7.37%	6.42%	-5.69%	6.03%
10-Endocrine, nutritional, and metabolic diseases and disorders	1.03%	7.61%	0.14%	7.43%
11-Diseases and disorders of the kidney and urinary tract	-1.44%	5.55%	-1.33%	4.53%
12-Diseases and disorders of the male reproductive system	-2.40%	-0.61%	-2.49%	0.89%
13-Diseases and disorders of the female reproductive system	-9.65%	-4.95%	-8.19%	-4.87%
14-Pregnancy, childbirth, and the puerperium	-1.91%	13.73%	-1.27%	13.27%
15-Newborns and other neonates with conditions originating in the perinatal period	10.97%	5.88%	10.54%	3.69%
16-Diseases and disorders of the blood and blood forming organs and immun. diseases	-4.97%	2.54%	-1.35%	0.35%
17-Myeloproliferative diseases and disorders, and poorly differentiated neoplasms	-14.81%	7.34%	-9.44%	4.47%
18-Infectious and parasitic diseases (systemic or unspecified sites)	-10.18%	3.49%	-5.21%	4.07%
19-Mental diseases and disorders	9.14%	-18.18%	2.89%	-6.71%
20-Alcohol/drug use and alcohol/drug induced organic mental disorders	9.34%	-14.49%	11.24%	-14.03%
21-Injuries, poisonings, and toxic effects of drugs	1.75%	-8.68%	1.43%	-6.83%
22-Burns	-28.14%	29.72%	-24.07%	20.41%
23-Factors influencing health status and other contacts with health services	0.72%	3.29%	0.03%	4.25%
24-Multiple significant trauma	35.93%	-6.09%	34.71%	-24.70%
25-Human immunodefiency virus infections	-8.95%	9.33%	-4.91%	9.09%

We note that the extreme values found in some categories and the shifts in inflation from one year to the next reflect the small number of observations in our sample.
One of the main purposes of computing inflation by groups of representative conditions is to be able to compute different inflation rates by hospital that can legitimately be used in a prospective payment system. By the previous statement we mean that the hospital should be compensated for increases in cost which do not result from its own direct actions. A hospital that has a disproportionate share of patients classified in a disease group whose costs rise faster than average should be compensated for this fact by having its payments rise by a rate higher than that used for other hospitals. On the other hand it would be contrary to the spirit of the prospective payment system to allow the payments to a certain hospital to rise faster

than the ones to other hospitals simply because its costs have risen faster without paying attention to the cause of the underlying cost increase. The previously computed hospital specific inflation does not discriminate between the possible causes of inflation in a given hospital. In table 6 below we compute the inflation rate of each hospital by a weigthed average of the MDC rates where the weights are each hospital's share of that MDC in total cost. The rates reflect differentials due only to case mix compositions. For this to be an accurate exercise one would have to have MDC inflation rates computed for the country as a whole so that the impact of a single hospital on the national rate could only be minor. This is unlikely to be the case here given that we only have 4 hospitals in our sample.

Table 6: Inflation due to different case-mix(MDC)

			LOS model	
All DRGs	**2001**	**2002**	**2001**	**2002**
University hospital (canton A)	0.52%	2.85%	1.38%	1.80%
3 regional hospitals (canton B)	-0.50%	3.35%	0.55%	2.82%

There is a considerable difference when comparing with the rates in table 4. Departures of specific hospitals form the overall inflation are much less pronounced here indicating that there could be hospital specific components of the changes in cost that are not due to a different case mix.

5 Sequential estimation of inflation

One problem with the general approach just described is that it is not practical to use from the perspective of constructing an index series, since by definition it implies that the models should be re-estimated every time new data becomes available. This would necessarily imply that all the values of the price index in previous periods would change, which is not in accordance with what is generally understood by a price index series. This is one of the criticisms that Diewert (1995) makes of the approaches that go under the general classification of stochastic approaches to index theory as described in previous sections.

We now present alternative methods that circumvent this problem.

5.1 Kalman filter algorithm

The proposition presented here is to develop price indices that can be calculated in real time and can be seen as slight modifications of the models in the previous section. The general principle is to combine the models above with updating algorithms generally known as Kalman Filters. To be more specific we have the following class of models:

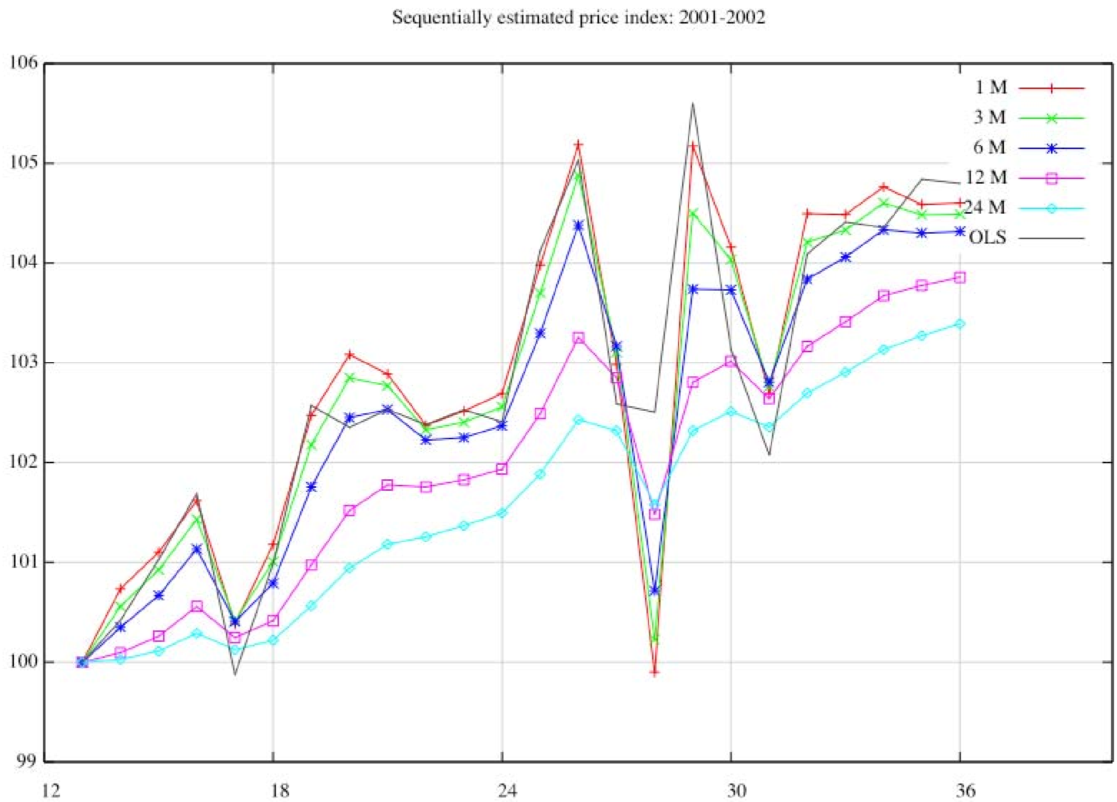
$$\delta_t = \delta_{t-1} + \sigma_\nu \nu_t$$
$$y_{nit} = \alpha_i + \delta_t + x_{nit}\beta_i + \sigma_\varepsilon \varepsilon_{nit}$$

where δ_t is now a random coefficient and the perturbations ν_t and ε_{nit} are jointly normally distributed and uncorrelated. Our estimate of δ_t is now given by $E(\delta_t|\Omega_t)$ where Ω_t represents all the information available at time t, that is $(y_{nis}, \alpha_i, x_{nis}, \beta_i, \forall i, \forall n, s = 1,...t)$. This quantity can be readily calculated from the Kalman filtering recursions. To better clarify the connection between these models and the ones in the previous section one can view the latter as extreme cases of the former. If one interprets the ratio $\sigma_\nu/\sigma_\varepsilon$ as a smoothing parameter then the models of the previous case correspond « loosely speaking » to the case $\sigma_\nu/\sigma_\varepsilon \to \infty$. The other extreme, where $\sigma_\nu/\sigma_\varepsilon \to 0$ corresponds to the case where δ_t does not change (in fact $\delta_t \to \bar{\delta}$ as $t \to \infty$) and $\bar{\delta}$ can be interpreted as the intercept of the equation above (after suitable normalization of the parameters α_i). In the notation of the model and in the description just made, the remaining parameters of the model are estimated using an initial period and then used as fixed to calculate the inflation rate in subsequent periods. This does not need to be the case. The remaining parameters can be given the same treatment as δ_t and can be sequentially updated as new information becomes available.

5.2 Results: sequential estimation of hospital inflation

To compute hospital inflation by the proposed method we need preliminary estimates of the parameters α_i and β_i. We use the sample from year 2000 to obtain these values, and apply the method described for the years 2001 and 2002. We then compare the price index obtained using this sequential method to the one previously obtained using an OLS procedure. As noted above, one needs to choose the parameter $\sigma_v/\sigma_\varepsilon$, which will act as a smoothing parameter. Guidance for the choice of $\sigma_v/\sigma_\varepsilon$ is provided in appendix 4. Essentially the sequential procedure described will generate a price index that is a closely related to a moving-average of the price index generated in the OLS setting. A certain value for $\sigma_v/\sigma_\varepsilon$ will imply that the moving average will be mostly based on a certain number of periods.

Figure 5: Monthly price index – sequential procedures.



Each line corresponds to the approximate number of periods that enter the weighted average of the price index and provides guidance to the choice of the variance of the price equation. It is noticeable that the shorter the period used for the price prediction, the closer the sequential estimate is to the OLS estimate, reflecting the theoretical calculations made. It is worthwhile to point out that the sequential estimates use values for α_i and β_i computed using only one year of data and that the OLS estimates use all the sample to estimate these parameters. The results suggest that if the goal is to use the OLS estimates then it is possible to do so in a sequential and implementable way. We note also when choosing parameters that imply a higher degree of smoothing one obtains price indices that are much less vulnerable to the excessive monthly variation. If one believes that this variation derives from insufficient sample sizes (at the DRG/month level) and from accounting practices then such filtering is advised. The optimal level of filtering will necessarily depend on our judgment about the dataset and on the periodicity of the calculation. Even if we do not find it justified to compute inflation on a monthly basis, the smoothing procedures that imply a one year or more averaging period constitute an alternative to simple year averages of prices. Naturally what was exemplified here with monthly data can be reproduced with annual data as continued data collection procedures make such data available.

6 Discussion

We have proposed a way to compute hospital PPI and inflation rates from routinely collected DRG and costs data. This approach is related to the hedonist price regression method, which captures price inflation after withdrawing the impact of the good's characteristics on its price. Here we control for the impact of the features of the hospital stays – its DRG classification and the length of stay. As expected our hospital inflation rate is quite different from the Swiss hospital CPI, suggesting that due attention should be paid to hospital specific PPI that takes into account the features of the health care industry.

The methods proposed are flexible enough to be made do mimic standard index concepts such as the Laspeyres index as well as to take into account shifting compositions of case-mix both at the national level and at the hospital specific level by appropriate choice of weights. So we can accommodate the changing composition of hospital health care over time. The indices proposed are based on an illness episode approach, and it take into account quality changes of health care provided measures of quality are available. The hospital PPI discussed is closer to hospitals production costs than the one computed by the US Bureau of Labor Statistics (BLS) as it is based on cost accounting data whereas the BLS index is based on price quotes for particular client bills and therefore includes th hospital desired margin.

A step further of the work presented here would be to compute hospital PPI for all hospitals in Switzerland and verify until what extent the results presented here are maintained all Swiss hospitals.

APPENDIX 3: WEIGHT DEFINITION

Consider the standard Laspeyres price index formula in a two period setting:

$$P = \frac{\sum_{d=1}^{D} q_d^0 p_d^1}{\sum_{d=1}^{D} q_d^0 p_d^0} = \frac{\sum_{d=1}^{D} q_d^0 p_d^0 \frac{p_d^1}{p_d^0}}{\sum_{d=1}^{D} q_d^0 p_d^0}$$

$$\cong \frac{\sum_{d=1}^{D} q_d^0 p_d^0 \left(1 + \log\left(\frac{p_d^1}{p_d^0}\right)\right)}{\sum_{d=1}^{D} q_d^0 p_d^0}$$

$$= 1 + \sum_{d=1}^{D} w_d^0 \log\left(\frac{p_d^1}{p_d^0}\right)$$

where q_d^0 d is the quantity of patients in DRG d in year 0, p_d^0 is the price(cost) of a patients in DRG d in year 0 and w_d^0 is the share of the total cost of DRG d in year 0. Hence we have the calculated inflation to be:

$$\sum_{d=1}^{D} w_d^0 \log\left(\frac{p_d^1}{p_d^0}\right)$$

In order to replicate the previous expression in a regression setting consider the following simple model:

$$\log\left(c_{id}^t\right) = \alpha + \beta T_{id}^t + \varepsilon_{id}^t$$

where t = 0, 1 is a time index, i is a patient index, d a DRG index, c_{id}^t is the cost of patient i in DRG d and period t and T_{id}^t is a time dummy equal to 1 if t = 1 and zero otherwise. Consider a WLS procedure with weights ω t id. The estimator for α is:

$$\hat{\alpha} = \frac{\sum_{d=1}^{D}\sum_{i=1}^{N_d^0}\omega_{id}^0 \log\left(c_{id}^o\right)}{\sum_{d=1}^{D}\sum_{i=1}^{N_d^0}\omega_{id}^0}$$

$$= \sum_{d=1}^{D}\frac{\sum_{i=1}^{N_d^0}\omega_{id}^0}{\sum_{d=1}^{D}\sum_{i=1}^{N_d^0}\omega_{id}^0}\sum_{i=1}^{N_d^0}\frac{\omega_{id}^0}{\sum_{i=1}^{N_d^0}\omega_{id}^0}\log\left(c_{id}^o\right)$$

$$= \sum_{d=1}^{D}\frac{\omega_{.d}^0}{\omega_{..}^0}\sum_{i=1}^{N_d^0}\frac{\omega_{id}^0}{\omega_{.d}^0}\log(c_{id}^0)$$

$$= \sum_{d=1}^{D}\frac{\omega_{.d}^0}{\omega_{..}^0}\log(\bar{c}_{.d}^0)$$

where N^0_d is the number of patients in DRG d in year 0, $\omega_{.d}^0 = \sum_{i=1}^{N_d^0}\omega_{id}^0$ is the sum of weights for DRG *d* in year *0*, $\omega_{..}^0 = \sum_{d=1}^{D}\sum_{i=1}^{N_d^0}\omega_{id}^0$ is the total sum of weights and $\bar{c}_{.d}^0$ is the (geometric) average cost of DRG *d* in year *0*. Likewise the estimator of β is:

$$\hat{\beta} = \sum_{d=1}^{D}\frac{\omega_{.d}^0}{\omega_{..}^1}\log(\bar{c}_{.d}^1) - \sum_{d=1}^{D}\frac{\omega_{.d}^0}{\omega_{..}^0}\log(\bar{c}_{.d}^0)$$

If we set $\omega_{.d}^1 = \omega_{.d}^0 = q_d^0 \cdot p_d^0$, i.e. the sum of weights for DRG d in both periods equal to the total cost of DRG *d* in period *0* then we have:

$$\hat{\beta} = \sum_{d=1}^{D}\frac{\omega_{.d}^0}{\omega_{..}^0}\log\left(\frac{\bar{c}_{.d}^1}{\bar{c}_{.d}^0}\right)$$
$$\hat{\beta} = \sum_{d=1}^{D} w_d^0 \log\left(\frac{\bar{c}_{.d}^1}{\bar{c}_{.d}^0}\right)$$

that is we have the price index defined initially. The condition $\omega_{.d}^1 = \omega_{.d}^0 = q_d^0 \cdot p_d^0$ can be achieved by setting:

$$\omega_{id}^t = \frac{\sum_{i=1}^{N_d^0} c_{id}^0}{N_d^t}$$

An analogous choice of weights can be made do obtain a Paasche index or a chain index.

Instead of using weights one could also sample patients from all hospitals with patients in a certain DRG in a given year having the probability $\frac{\omega_{.d}^0}{\omega_{..}^0}$ of being sampled.

References

Bartlett, M. S. (1947). The Use of Transformations. *Biometrics*, Vol. 3, No. 1, pp. 39-52.

Berndt, Ernst R.; Cutler, David M.; Frank, Richard G.; Griliches, Zvi; Newhouse, Joseph; Triplett, Jack E. (2001). Price Indexes for Medical Care Goods and Services: An Overview of Measurement Issues.. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 141-98. 2001

Berndt, Ernst R; Busch, Susan H; Frank, Richard G (2001). Treatment Price Indexes for Acute Phase Major Depression.. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., *NBER Studies in Income and Wealth*, vol. 62. Chicago and London: University of Chicago Press. p 463-505.

Bickel, Peter J.; Doksum, Kjell A. (1981). An Analysis of Transformations Revisited Journal of the *American Statistical Association* (in Theory and Methods), Vol. 76, No. 374, pp. 296-311.

Box, G. E. P.; Cox, D. R. (1964). An Analysis of Transformations. *Journal of the Royal Statistical Society. Series B* (Methodological), Vol. 26, No. 2, pp. 211-252

Catron, Brian; Murphy, Bonnie (1996). Hospital price inflation: what does the new PPI tell us. *Monthly Labor Review*, July 1996

Chevrou-Severac, Helena; Jeanrenaud, Claude; Wasserfallen, Jean-Blaise (2003). Cause de l'acroissement des depenses de sante: hausses des couts ou ameiloration des prestations. Rapport de l'Institut de Recherches Economiques et Regionales. Université de Neuchâtel.

Cutler, David M; McLelland, Mark; Newhouse, Joseph P.; Remhler, Dahlia (2001). Pricing Heart Attack Treatments. [Collective Volume Article] Me*dical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 305-47.

Diewert (1995). On the Stochastic Approach To Index Numbers. Department of Economics, University of British Columbia, Discussion Paper No. 95-31, 41 pp.

Eichhorn, W. (1976). Fisher's tests revisited. *Econometrica* 44, 247-256.

Ford, Ina Kay; Ginsburg, Daniel H. (2001). Medical Care in the Consumer Price Index. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 203-19. 2001

Griliches, Zvi ; Iain Cockburn (1994), "Generics and new goods in pharmaceutical price indexes." American Economic Review 84 (5), pp. 1213-32.

Griliches, Zvi (1992). Introduction. in *Output measurement in the service sectors*. Ed. Zvi Griliches, 1-22. NBER Studies in Income and Wealth, vol. 56. Chicago: University of Chicago Press

Griliches, Zvi. (1967) Hedonic Price Indexes Revisited: Some Notes on the State of the Art, *Proceedings of the Business and Economic Statistics Section*, American Statistical Association, 1967, pp. 324-332.

Griliches, Zvi. (1971). Hedonic Price Indexes of Automobiles: An Econometric Analysis of Quality Change, in Zvi Griliches (ed.), *Price Indexes and Quality Change*, Cambridge: Cambridge University Press

Heidenreich, Paul; McClellan, Mark. (2001). Trends in Heart Attack Treatment and Outcomes, 1975-1995: Literature Review and Synthesis.. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 363-409. 2001.

Hinkley, D. V.; Runger, G. (1984). The Analysis of Transformed Data. *Journal of the American Statistical Association*, Vol. 79, No. 386., pp. 302-309.

Holly, A.; Pentsak , Yevhen (1994). "Maximum Likelihood Estimation of the Conditional Mean E(y| x) for Skewed Dependent Variables in Four-parameter Families of Distribution" unpublished manuscript

Jacobzonne, Stéphane ; Martin, Edouard; Perrin, Vincent and Werle, Julien (1997). “Une approche hédonique de la formation des prix des médicaments remboursable” Economie & Prévision, numéro 129-130, Juillet-Septembre 1997, pp. 73—99.

Ribeiro, Tiago (2003)."Hidden Markov Models and their Applications to Estimation, Forecasting and Policy Analysis in Panel Data Settings" (PhD dissertation - UC Berkeley)

Gertler, Paul; Raube, Kristiana and Ribeiro, Tiago (2003). Estimation of marginal costs for California Hospitals, unpublished manuscript UC Berkeley

Rosen, Sherwin. (1974) "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, Vol. 82, Jan./Feb. 1974, pp. 34-55.

Scitovsky, Anne A. (1964). An index of the cost of medical care - a proposed new approach. In The economics of health and medical care. Ed. Solomon, J. Axelrod, 128-42. Ann Arbor: Bureau of Public Health Economics, University of Michigan.

Scitovsky, Anne A. (1967). Changes in the cost of treatment of selected illnesses, 1951-65. *American Economic Review* 57(5): 1182-95

Shapiro, Irving; Shapiro, Matthew D; Wilcox, David W. (2001). Measuring the Value of Cataract Surgery. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 411-37. 2001.

Triplett, Jack E. (Editor), (1999), Measuring the prices of medical treatments, Brookings Institution Press, Washington, D. C.

Triplett, Jack E. (2001). What's Different about Health? Human Repair and Car Repair in National Accounts and in National Health Accounts. [Collective Volume Article] *Medical care output and productivity*. Cutler, David M. Berndt, Ernst R., eds., NBER Studies in Income and Wealth, vol. 62. Chicago and London: University of Chicago Press. p 15-94. 2001