COMPARISON OF BAYESIAN ESTIMATES OF HEALTH CARE COSTS FOR CZECH AND SLOVAKIAN INSURANCE COMPANIES

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Abstract: *This paper presents an application of the Bayesian inference to estimate health care expenses by health insurance companies in the Czech Republic and Slovakia. In particular, the Bühlmann-Straub model is applied onto real data from all seven Czech and three Slovakian health insurance companies in order to calculate the credible health care costs per person and the corresponding credibility factors for each company. The results of Bühlmann-Straub model show that while the largest insurance companies can reliably predict the health care costs for the subsequent time period based on its own statistical data, the smaller companies can find out credible estimation of health care costs per person, taking into account data from all comparable healthcare insurance companies.*

Keywords: *Credibility Model, Bayesian Estimation, Bühlmann-Straub model, Health Insurance, Health Insurance companies.*

JEL Classification: *C11,C22, G22.*

Introduction

The history of the Czech Republic is interwoven with the history of Slovakia, for both the countries were one state up to 1th January 1993, therefore their further independent evolution is expected to be similar. This paper deals with problems related to health care costs refunded from the health insurance, hence nowadays, questions related to funding of the health care in post-communist countries are discussed.

Article provides estimates and comparisons of health care costs per person in Czech and Slovak health insurance companies. For estimating was used empirical Bühlmann-Straub credibility model, which was originally created for calculating premiums for short term insurance contracts [2]. The technique calculates a premium for a risk using two ingredients: past data from the risk itself and collateral data, i.e. data from other sources considered to be relevant.

Our application of this model to estimate healthcare costs per person in health insurance companies can be considered as original. The situation in the collection of insurance premiums of health insurance companies is fundamentally different compared with commercial insurance companies. Premium is not proportional to the health risks of the insured person, but depends only on his income. Therefore, the model was not used to estimate the premium, but to estimate the healthcare costs per person, which vary among health insurance companies for several reasons. It could be the amount of premium income, age of the insured persons, the structure of reimbursable medical activities, but also inefficient spending of funds.

Credibility estimates are actually information on level of these costs, if we estimate them as a linear function of the past data from the health insurance company itself and based on collateral data from other health insurance companies. The credibility formula for estimation healthcare costs per person P_c in next year is in the form:

$$P_c = Z\,P_r + (1-Z)\,\mu \tag{1}$$

where P_r is estimation based on own past data in insurance company, μ is estimation based on collateral data and Z is a number between zero and one, known as the credibility factor. Credibility factor Z is a measure of how much reliance the company is prepared to place on the data from the company itself.

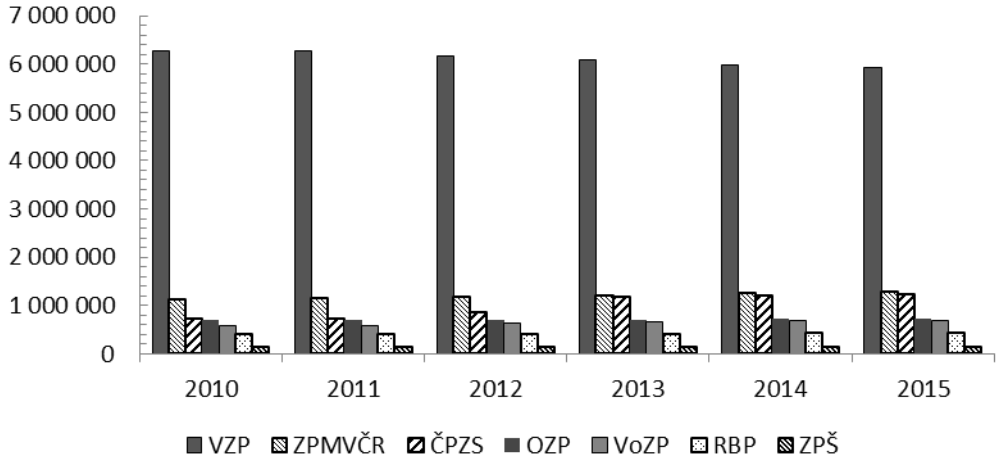
1 Statement of a problem

Each employed citizens of the Czech Republic and Slovakia, including foreigners living or being employed in each of these countries, have to pay insurance premium as a contribution to the public health insurance. Health insurance for the unemployed people, children, women on the maternity leave and retired people is paid by the state. Thanks to the health insurance system there is availability of health care for all the insured persons, regardless of the height of their payments.

Currently there are seven health insurance companies in the Czech Republic - Všeobecná zdravotní pojišťovna (VZP), Zdravotní pojišťovna ministerstva vnitra České republiky (ZPMVČR), Česká průmyslová zdravotní pojišťovna (ČPZP), Oborová zdravotní pojišťovna (OZP), Vojenská zdravotní pojišťovna (VoZP), Revírní bratrská pojišťovna (RBP) and Zaměstnanecká pojišťovna Škoda (ZPŠ).

Fig. 1 presents the number of insured persons in the time period 2010-2015 for each Czech health insurance company. Evidently, VZP insures a major part of the Czech population, the number of persons it insures is even higher than sum of persons insured by all other health insurance companies. During the considered time period the number of persons insured by VZP decreases moderately, while the number of persons insured by some of the others insurance companies (especially ČPZS) increases.

Fig. 1: Number of insured persons in the Czech Republic

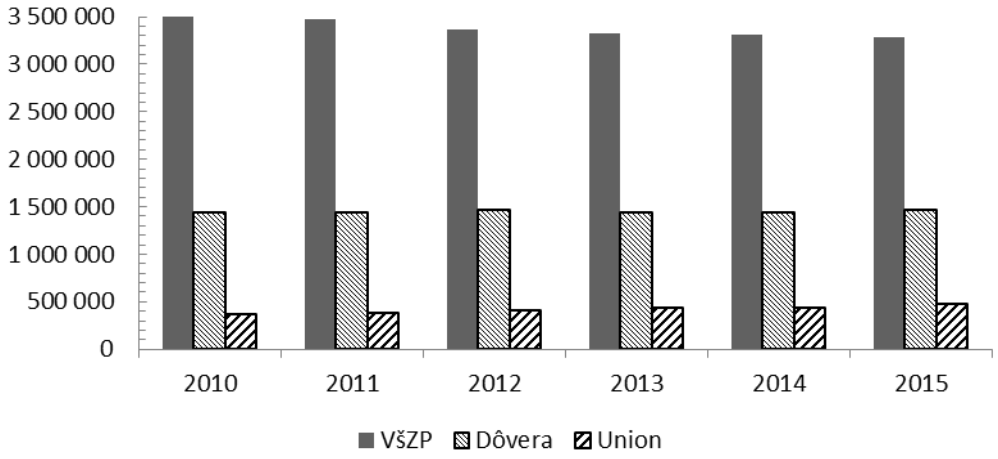


Source: Yearbooks of health insurance companies

There are three health insurance companies in Slovakia - Všeobecná zdravotná poisťovna, Dôvera zdravotná poisťovňa, and Union poisťovňa.

Fig. 2 presents the number of insured persons in the time period 2010-2015 for each Slovakian health insurance company. Evidently, Všeobecná zdravotná poisťovňa (VšZP) insures major part of Slovakian population, the number of persons it insures is even higher than sum of persons insured by both other health insurance companies. During the considered time period the number of persons insured by VšZP decreases moderately, especially between 2011 and 2012.

Fig. 2: Number of insured persons in Slovakia



Source: Yearbooks of health insurance companies

To be able to ensure financial means, every health insurance company needs to appraise health care expenses for the subsequent time period. It is appropriate to use information about health care expenses based on the data from all the health care insurance companies in the country. For this purpose, it is necessary to estimate these expenses by applying mathematical and probabilistic models, for example those based on Bayesian analysis. Other possibilities of using Bayesian estimates in insurance are discussed in [2]-[12].

The time series of the total health care expenses and number of insured persons are the basis for estimates of the expenses of the health insurance companies in Czech Republic and in Slovakia. Data from all three Slovakian health insurance companies covering time period 2010-2015 are used for computation in this paper. Bühlmann-Straub model is applied to estimate the health care costs per person for the subsequent time period. Estimation of the health care costs for each health insurance company is a linear combination of estimated costs based on inner historical data of this insurance company and estimations based on outer information related to health care costs from all insurance companies. This approach taking both the own and the undertaken information into account guaranties objective estimates of the health care costs.

2 Data and methodology

The health care insurance in the Czech Republic is provided by seven health care insurance companies and in Slovakia by three health insurance companies.

Computations presented in this paper are based on data extracted from their yearbooks covering time period 2010-2015, available on their websites.

Bühlmann-Straub model used in this paper follows here.

Let the insurance company, for which the estimates of health care expenses (resp. net insurance premium) are computed, is one of N insurance companies. Total expenses in previous n years are known for all these insurance companies.

Let Y_{ij} is a variable, describing total health care costs of the i-th health insurance company in the Czech Republic ($i = 1, \ldots, N$; $N = 7$) or in Slovakia ($i = 1, \ldots, N$; $N = 3$) in the j-th year ($j = 1, \ldots, n$; $n = 6$).

Let P_{ij} stands for the number of insured person for each health insurance company $i = 1, \ldots, N$ and each year $j = 1, \ldots, n$.

According to [1]-[5], standardized health care costs $X_{ij} = Y_{ij} / P_{ij}$, satisfy the following conditions:

- For every $i = 1, \ldots, N$ the distribution of variable X_{ij} depends on an unknown parameter θ_i, equal for all the years $j = 1, \ldots, n$.
- For every $j = 1, \ldots, n$ the variables $X_{i1} / \theta_i,\ X_{i2} / \theta_i, ..., X_{in} / \theta_i$ are independent, but not necessarily identically distributed.

Then, two functions depending on j can be defined as:

$$E\left(X_{ij} / \theta_i\right) = m(\theta_i);\quad D\left(X_{ij} / \theta_i\right) = \frac{s^2(\theta_i)}{P_{ij}} \tag{2-3}$$

The above mentioned relations express conditions satisfied for every risk $i = 1, \ldots, N$. Relationships between risks are described by the following conditions:

- Parameters of risks $\theta_1, ..., \theta_N$ are random variables, which are independent and identically distributed.
- For $i \neq k$ are (θ_i, X_{ij}) and (θ_k, X_{km}) independent.

Because parameters of risk $\theta_1, ..., \theta_N$ are identically distributed, values $E(m(\theta_i))$, $D(m(\theta_i))$, $E(s^2(\theta_i))$ are independent on i and can be denoted as $E(m(\theta))$, $D(m(\theta))$, $E(s^2(\theta))$.

Following formulas are used to simplify the calculation:

$$P_i = \sum_{j=1}^{n} P_{ij};\quad P = \sum_{i=1}^{N} P_i;\quad Y_i = \sum_{j=1}^{n} Y_{ij};\quad Y = \sum_{i=1}^{N} Y_i \tag{4-7}$$

$$\overline{X}_i = \frac{1}{P_i} \sum_{j=1}^{n} P_{ij} X_{ij} = \frac{1}{P_i} \sum_{i=1}^{n} Y_{ij};\quad \overline{X} = \frac{1}{P} \sum_{i=1}^{N} \sum_{j=1}^{n} P_{ij} X_{ij} = \frac{1}{P} \sum_{i=1}^{N} P_i \overline{X}_i \tag{8-9}$$

$$P^* = \frac{1}{Nn - 1} \sum_{i=1}^{N} P_i \cdot \left(1 - \frac{P_i}{P}\right) \tag{10}$$

Then according to [1] and [4]-[12], the rules for estimating the parameters $E(m(\theta))$, $D(m(\theta))$, $E(s^2(\theta))$ are:

$$estE(m(\theta)) = \overline{X}; \quad estE(s^2(\theta)) = \frac{1}{N(n-1)} \sum_{i=1}^{N} \sum_{j=1}^{n} P_{ij} \left(X_{ij} - \overline{X}_i \right)^2 \tag{11-12}$$

$$estD(m(\theta)) = \frac{1}{P^*} \left\{ \begin{array}{l} \frac{1}{Nn-1} \sum_{i=1}^{N} \sum_{j=1}^{n} P_{ij} \left(X_{ij} - \overline{X} \right)^2 \\ - \frac{1}{N(n-1)} \sum_{i=1}^{N} \sum_{j=1}^{n} P_{ij} \left(X_{ij} - \overline{X}_i \right)^2 \end{array} \right\} \tag{13}$$

Credibility factor for the *i*-th risk is calculated in form

$$Z_i = \frac{P_i}{P_i + \frac{E(s^2(\theta))}{D(m(\theta))}} \tag{14}$$

The value of credibility factor shows the rate of reliability of own data for every health insurance company.

The estimates of parameters $E(m(\theta)), D(m(\theta)), E(s^2(\theta))$ are the same for all the insurance companies. Credibility factor Z_i differs for each company. The higher is the value of risk rate P_i, the higher is the value of credibility factor Z_i.

Then, according to [1]-[8], for the estimation of credible health care for the *i*-th risk, the following formula is used.

$$\begin{aligned} E(m(\theta) / X) &= Z_i \overline{X}_i + (1 - Z_i) E(m(\theta)) \\ &= Z_i \overline{X}_i + (1 - Z_i) \overline{X} \end{aligned} \tag{15}$$

3 Problem solving

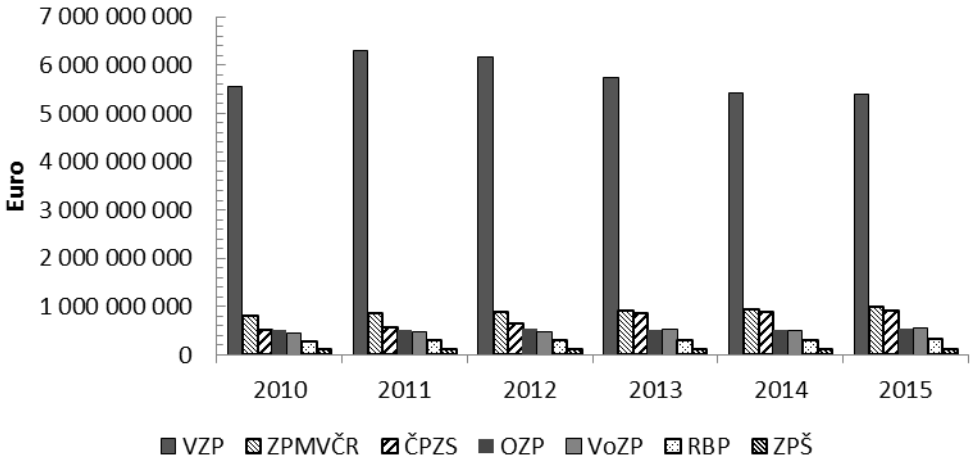
Bühlmann-Straub model was applied to compute credible net premium, here used as health care cost per person. The computation was based on a set of real data published in yearbooks of Czech and Slovakian health insurance companies.

3.1 Results for the Czech Republic

The basis for the computation of credible health care costs per person according to formula (15) was the data from all Czech health insurance companies in years 2010-2015, namely amount of persons insured by particular health insurance company (P_{ij}) and total health care costs paid by particular health insurance company (Y_{ij}) (in €). These values are shown in Fig. 1 and Fig. 3. Amount of insured persons in each health insurance company and each year presents the rate of insurance risk.

Total amount of insured persons P_i insured by each insurance company *i* in the whole period, total costs Y_i paid by each insurance company in the whole period, and average insurance costs per person in the whole period $\overline{X}_i$ for each insurance company were computed according to (4), (6) and (8). Results of computation of these characteristics are presented in Tab. 1.

Fig. 3: Health care costs in the Czech Republic



Source: Yearbooks of health insurance companies

Tab. 1: Chosen characteristics computed for the Czech health insurance companies

	P_i	Y_i	$\overline{X}_i$
VZP	36 705 665	34 531 321 284	940.76
ZPMVČR	7 203 659	5 413 941 518	751.55
ČPZS	5 907 897	4 382 431 857	741.79
OZP	4 255 418	3 150 649 418	740.39
VoZP	3 869 096	2 998 838 815	775.07
RBP	2 523 517	1 774 482 880	703.18
ZPŠ	825 230	658 663 744	798.16

Source: Authors

Then, following values are computed:

$$P = \sum_{i=1}^{7} P_i = 61\,290\,482; \quad Y = \sum_{i=1}^{7} Y_i = 52\,910\,329\,514; \quad \overline{X} = 863.27$$

Then values of $X_{ij} = \frac{Y_{ij}}{P_{ij}}$, representing standardized health care costs per person in each year and each insurance company (in €), are computed. These values are then used to estimate parameters of the model according to (11)-(13).

$$estE(m(\theta)) = 863.27;\ estE(s^2(\theta)) = 2\,514\,319\,266;\ estD(m(\theta)) = 14\,634.56$$

According to (14), values of credibility factors Z_i are computed for every health insurance company. It is necessary to find these values to be able to compute credible estimations of net insurance costs per person according to (15). Values of credibility factors and credible health care costs are presented in Tab. 2. The value of credibility factor Z_i shows the effect of inner data from the particular Czech health insurance

company on the value of the credible health care costs per person. (1-Z_i) shows the same effect for the outer data from all the Czech health insurance companies.

Values of credible estimates of the health care costs per person can be used for appraising net insurance premium for the following year in every Czech health insurance company. Since the data used for computations covers period 2010-2015, computed values of credible estimates of average costs are estimates of net health care costs per person for each Czech health insurance company in 2016.

Tab. 2: Credibility factors Z_i and credible health care costs per person (in €) for the Czech health insurance companies

	Z_i	Credible health care costs
VZP	0.9953	940.40
ZPMVČR	0.9767	754.16
ČPZS	0.9717	745.23
OZP	0.9612	745.15
VoZP	0.9575	778.82
RBP	0.9363	713.38
ZPŠ	0.8277	809.38

Source: Authors

Tab. 2 shows the differences in values of credibility factors Z_i among the Czech health insurance companies, and subsequently big differences in estimates of net insurance costs per person in Euros.

Value Z_i = 0.9953 for major Czech insurer VZP shows that this health insurance company can rely from 99.53 % on its own. The second major insurer ZPMVČR has the credibility factor 0.9767. It means that this major insurance company can rely from 97.67 % on its own data and from 2.33 % on the information from all the insurance companies. Almost all of the health insurance companies have the value of credibility factor higher than 0.9, so the importance of their inner information is very high.

On the other hand, the credibility factor belonging to ZPŠ, with the smallest number of insured persons, has the smallest computed value 0.8277. This insurance company can rely only from 82.77 % on its own data and from 17.23 % on the information from all the insurance companies.

The values of credible health care costs per person differs are from 713.38 to 940.40 €. We can observe quite a big difference among the values of both credibility factors and health care costs. These results of credible health care costs per person we can compare with estimations of these values of several health insurance companies. These comparisons we can see in Tab. 3. By these values we can see, that the differences of our estimations and estimations of health insurance companies are not so big, so this theory is a good instrument for this area. It is remarkable, that any estimate of insurance company is higher than the credible estimate.

Tab. 3: Comparison of credible health care costs with estimation of health care costs/person by insurance companies for the year 2016

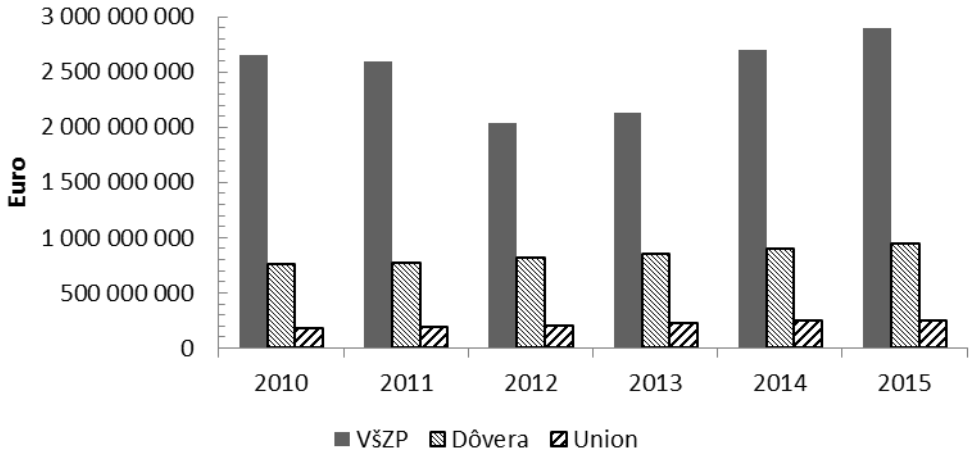
	Credible health care costs/person for 2016	**Estimation of health care costs/person by insurance companies for 2016**
VZP	940.40	994.64
ZPMVČR	754.16	Data not available.
ČPZS	745.23	809.14
OZP	745.15	822.94
VoZP	778.82	Data not available.
RBP	713.38	816.33
ZPŠ	809.38	898.59

Source: Authors and yearbooks of health insurance companies

3.2 Results for Slovakia

The basis for the computation of credible health care costs per person was the data from all Slovakian health insurance companies again in years 2010-2015. Amount of persons insured by particular health insurance company (P_{ij}), presenting the rate of insurance risk, is shown in Fig. 2 and total health care costs paid by particular health insurance companies in € (Y_{ij}) are shown in Fig. 4.

Fig. 4: Health care costs in Slovakia



Source: Yearbooks of health insurance companies

Values of characteristics P_i (total amount of persons insured by each insurance company i in the whole period), Y_i (total costs paid by each insurance company in the whole period), and $\overline{X}_i$ (average insurance costs per person in the whole period for each insurance company) are presented in Tab. 4. These characteristics were computed for all three Slovakian insurance companies in the similar way as the characteristics in the case of the Czech Republic.

Tab. 4: Chosen characteristics computed for the Slovakian health insurance companies

	P_i	Y_i	$\overline{X}_i$
VšZP	20 274 951	15 013 311 764	740.49
Dôvera	8 684 629	5 039 000 000	580.22
Union	2 503 597	1 274 760 630	509.17

Source: Authors

Then, the following values are computed:

$$P = \sum_{i=1}^{3} P_i = 31\,463\,177; \quad Y = \sum_{i=1}^{3} Y_i = 21\ 327\ 072\ 394; \quad \overline{X} = 677.84$$

Then the values of $X_{ij} = \frac{Y_{ij}}{P_{ij}}$, representing standardized health care costs per person in each year and each insurance company (in €). These values are then used to estimate parameters of the model:

$$estE(m(\theta)) = 677.84; \quad estE(s^2(\theta)) = 15\,324\,615\,762; \quad estD(m(\theta)) = 11\,012.44$$

Values of credibility factors and credible health care costs are presented in Tab. 5. The value of credibility factor Z_i shows the effect of inner data from the particular Slovakian insurance company on the value of the credible health care costs per person. $(1\text{-}Z_i)$ shows the same effect for the outer data from all the Slovakian insurance companies. These credible estimates of the health care costs per person can be used for appraising net insurance premium for the year 2016 in every Slovakian insurance company.

Tab. 5: Credibility factors Z_i and credible health care costs per person (in €) for the Slovakian health insurance companies

	Z_i	**Credible health care costs**
VšZP	0.9358	736.46
Dôvera	0.8619	593.70
Union	0.6427	569.43

Source: Authors

Tab. 5 shows the differences in values of credibility factors Z_i among the Slovakian health insurance companies, and subsequently big differences in estimates of net insurance costs per person in Euros. Value Z_i = 0.9358 for major Slovakian insurer VšZP shows, that this health insurance company can rely from 93.58 % on its own. The second major insurer Dôvera has the credibility factor 0.8619. This insurance company can rely from 86.19 % on its own data and from 13.81 % on the information from all the insurance companies. Even greater effect of outer data on credible health care costs is evident at the smallest health insurer Union. The health insurance company Union has to rely on outer data from more than 35 %.

These results of credible health care costs per person we cannot compare with estimates of these values of health insurance companies for the year 2016, because data are not available.

4 Discussion

This section presents comparison of the results of Bühlmann-Straub model applied on the data from health insurance companies in the Czech Republic and Slovakia. The Czech Republic and Slovakia were established in 1993 after two federative republics of former Czechoslovakia decided to split into two independent states. Therefore, the similarity of these healthcare systems is expectable.

Computed values of the credibility factors Z_i are presented in Tab. 2 (the Czech Republic) and Tab. 5 (Slovakia). The highest values of the credibility factor Z_i belong to major health care insurance companies in each country, 0.9953 for Všeobecná zdravotní pojišťovna (VZP) in the Czech Republic and 0.9358 for Všeobecná zdravotná poisťovňa (VšZP) in Slovakia. These insurers originate from the same company.

Since the order of the health insurance companies in tables 1, 2, 4, 5 is given by the total number of insured persons, it is evident (in each country) that the higher is the amount of insured persons P_i, the higher is the value of the credibility factor Z_i. Then, values of the credibility factor in the Czech Republic are higher than in Slovakia, but the range of these values is significantly narrower in the Czech Republic.

The values of credible health care costs per person (in €) are again presented in Tab. 2 (the Czech Republic) and Tab. 5 (Slovakia). Similarly to the results of credibility factors, the highest values of the credible health care costs belong to major health insurers in both mentioned countries. The highest credible health care costs in the Czech Republic, 940.40 €/person is estimated by VZP, and the highest credible health care costs in Slovakia, 736.46 €/person is computed for VšZP. The second highest credible health care costs 809.38 €/person belong to the minority health insurer in the Czech Republic, whereas the minority health insurance company in Slovakia estimates the lowest health care costs (only 551.53 €/person). The difference between the highest and the lowest credible health care cost per person is more than 220 € in the Czech Republic, and almost 170 € in Slovakia. The highest computed Slovakian credibility health care cost 709.9 €/person is comparable to the lowest Czech credibility health care cost 705.84 €/person.

Tab. 3 contains comparisons of credible health care costs with estimation of health care costs/person by Czech insurance companies for the year 2016. Data for comparison are not available for Slovaks insurance companies.

Values of the credibility factor evince similar characteristic in the Czech Republic and Slovakia, but the credibility health care costs in studied countries seem to be significantly different. However, the origin of these differences falls beyond the scope of this paper.

Conclusion

Every health insurance company needs to appraise its costs for the following time period. Estimates of these costs can be computed by applying Bayesian analysis, especially Bayesian models of credibility.

Results obtained by applying Bühlmann-Straub model on real data published by Czech and Slovakian health insurance companies, namely height of health insurance costs paid by insurance companies and amount of persons insured by these companies in years 2010-2014, show differences in estimations of health care costs per person among the insurance companies and mainly between the Czech and the Slovak Republic.

By applying Bühlmann-Straub model on the considered data, values of credibility factor are computed for each Czech and Slovakian health insurance companies. These values show the effect of the inner data from particular insurance companies on the value of credible health care costs per person. All insurance companies should bother both inner and outer data, however, the majority effect on the results relates to the inner data of particular health insurance company.

The computed values of the credible health care costs can be used to estimate the real health care costs for the following time period in every insurance company. This information is very important for estimating financial means. Despite the fact that the history of the Czech Republic and Slovakia is interwoven, real health care costs and their future estimations differ a lot.

Acknowledgement

This contribution was supported by SGS University of Pardubice, FEA, No. SGS_2016_023, "Ekonomický a sociální rozvoj v soukromém a veřejném sektoru".

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