Deviations in Birth Rates with Respect to the Day of the Week and the Month for a 100 Year Period Regarding Social and Medical Aspects in Explaining Models

Fabian Schuster[1], Thomas Ostermann[2], Reinhard Schuster[3] and Timo Emcke[4]

[1]*Faculty of Law, European University Viadrina Frankfurt (Oder), 15230 Frankfurt (Oder), Germany*

[2]*Chair of Research Methodology and Statistics in Psychology, Witten/Herdecke University, 58313 Herdecke, Germany*

[3]*Chair of Department of Health Economics, Epidemiology and Medical Informatics, Medical Advisory board of Statutory Health Insurance in Northern Germany (MDK), 23554 Lübeck, Germany*

[4]*Chair of Department of Prescription Analysis, Association of Statutory Health Insurance Physicians, 23795 Bad Segeberg, Germany*

Keywords: Sunday Births, Long Time Considerations, Social Aspects, Instable Problems, Shannon Entropy, Gini Coeffient.

Abstract: During the last hundred years the birth rates on Sundays changed dramatically with a neutral point around 1955. Modern birth regulation is considered as the main reason for that. Medical backgrounds for this situation were discussed in the 1970s. Prior to that no analysis has relevant case numbers. The time from conception to birth measured in days is divisable by 7. The time of conception is relevant in relation to social aspects. Conception rates can be determined under the assumption that we can split up the population in a low and a high risk share. This consideration principally leads to an instable problem on a discrete cyclic space. But using some limiting considerations we get a numerically stable solution with feasible characteristics. For observing long time changes we need a relevant smoothing operator. In numerical calculations we look for a quadratic minimum solution or alternatively a linear program. For the discussion of inequality the concept of Shannon entropy as well as and Lorenz curve and Gini coefficient are relevant.

1 INTRODUCTION

We will consider, how the birth rate per weekday has changed in the last hundred years using data of the statutory health and care insurances. Reduced birthrates at weekends are usually discussed in the context of elective interventions. Larger birth rates at Sundays at the beginning of the 20th century should be discussed in the social context. One has to take into account that it is not possible to measure real birth rates from 1900-1950 but only the component related to insurance benefits decades later. Even survival rates may depend on weekday of birth. On the other hand the benefits of health insurance may depend on the underlying risk structure. Even the health status ("medical age") may also depend on the weekday of birth.

Next we consider different daily birth rates and health costs with respect to the month of birth during different decades of the last century. Social and medical influences cause short and long term changes. In order to avoid large variations we use a 5 year smoothing of data. Interesting points are the day of birth and day of fertilization 100-85 years ago with varying social background. Large amounts of data are required to determine significant statistical effects. For this time

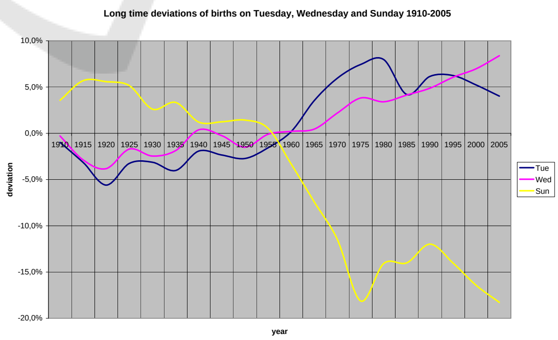

Figure 1: Long term development of birth rates on Tuesday, Wednesday and Sunday 1910-2005.

Schuster F., Ostermann T., Schuster R. and Emcke T.
Deviations in Birth Rates with Respect to the Day of the Week and the Month for a 100 Year Period Regarding Social and Medical Aspects in Explaining Models.
DOI: 10.5220/0006114900410047
In *Proceedings of the 10th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2017)*, pages 41-47
ISBN: 978-989-758-213-4

period no register data are digitally available in the extend needed. One has to take into account the extensive migration movements during the last 100 years. A possible solution might be given by aggregated digital administrative data of health and care insurances. But precise resolution (day) is rarely available after aggregation has been done for other reasons. The first discussion of the influence of the weekday of birth on a large data base was given in (Macfarlane, 1978) and (Mathers, 1983) using birth data of the seventies, our data focuses on some decades before. Furthermore the number of births with respect to the weekday differs much from the current pattern. Related backgrounds are discussed in the stated references (cf.(Kibele et al., 2013), (Klein et al., 2001), (Klein and Unger, 2002), (Lampert and Kroll, 2014), (Ma et al., 2012), (Mackenbach, 2006), (Schnell and Trappmann, 2006), (Schuster and Emcke, 2016), (Ostermann and Schuster, 2015)).

2 MATERIAL AND METHODS

We use health and care insurance data from a German federal state. With respect to sufficient statistical significance in the care insurance field we can go as far back as people born in 1905 by using data from 1998 till 2006, in the health insurance data from 2006 one can track back until 1920. Although we only need aggregated data, such data with a weekday resolution are rarely available.
We use the script language perl in order to aggregate data and for the association of day of the week and date. If we refer to birth rates with respect to months we have to take into account their different lengths. Gender was only available for the care insurance data. The detailed insurance can be identified by a 9-digit identification code (IK-number). We used a reference table containing the insurance type in order to get a known social indication.
If we use drug data, there is information about additional private payment of patients. Patients with low social status have an additional payment exemption. There is also a mixed status in which patients get an additional payment exemption after having payed a certain amount themselves. We are interested in the social circumstances during birth, but we measure the social status many years later. A Markov model for transition of states would be useful. But there is no real information about transition rates. If we assume that the states are stable, we underestimate social effects.
Another type of analysis could combine low and high risk at birth with a survival in the following categories: first three days after birth and mothers with an age under or over 50 years. A derived, more detailed refinement could lead to mortality tables in dependence of the day and month of birth. Due to the low availability of historical information this remains a modeling challenge.
The time from the last menstrual period (LMP) to childbirth is usually taken as 40 weeks or 280 days. Pregnancy from conception to childbirth is 38 weeks or 266 days long. But there are no large scale measurements for mean values and standard deviations and in particular about deviations from normal distribution. We can divide the population into two subsets with respect to high and low pregnancy risk: $X = X_1 + X_2$ as random variables. Let $s(X)$ be the standard deviation of X. We use $s(X_1) < s(X_2)$. It is known from literature that we have $9 < s(X) < 13$. We use $s(X_1) = 1,2,3$. X_1 leads to increasing peaks, X_2 gives a nearly uniform variation to all days. If fertilization data would be given, the distribution of the random variable length of pregnancy would be a smoothing parameter on cyclic space (with discretization to days of week). But if we have given the birth data and want to derive the weekday distribution of the fertilization we get an inversion operator which tends to be instable. Constraints lead to numerical stabilization. We start with a quadratic-deviations model. Let f(i) be the observed deviation from 1/7 for likelihood of birth at day i (i = 0, 1,...,6) and w(i) the fertilization deviation pattern at day i (i = 0, 1,..., 6). Than $d_s(j)$ shall be the translation of j days by normal distribution with standard deviation s using integer intervals. We look for the quadratic minimum:

$$\sum_{i=0}^{6} \left(f(i) - \sum_{j=-30}^{30} d(i-j)w(j) \right)^2 \longrightarrow \text{Min!}$$

with the constraints $-1 < -a < w(i) < b < 1$. Practically we use $a = b = 1/(7*5)$ in order to limit the deviation for each day with respect to the mean of the week to 20 %. Alternatively we could use linear programming:

$$\left| f(i) - \sum_{j=-30}^{30} d(i-j)w(j) \right| < s, s \longrightarrow \text{Min!}$$

For calculations we use Microsoft Excel and Mathematica from Wolfram Research.
In order consider the different deviations during the considered time period we use the concept of Shannon entropie $\sum_{i=0}^{6} -p_i \ln(p_i)$ for the birth rates p_i at day i. The same considerations we can adopt to months instead of the weekdays. Alternative measures of the inequality are given by the Lorenz Curve and the related Gini coefficient. In order to quan-

tify the deviation from the equal distribution we define $x_i = p_i - 1/7$ and from $\sum_{i=0}^{6} p_i = 1$ it follows $\sum_{i=0}^{6} x_i = 0$. The function $(1/7+x)\,ln(1/7+x)$ has the Taylor series: $-ln(7)/7 + x(1-ln(7)) + 7x^2/2 - 49x^3/6 + O(x^4)$. As result we get a constant if we sum up the index i from 0 to 6 (with respect to the weekdays, with respect to the months we have to sum up from 0 to 11). Therefore the entropy reflects a quadratic (non-linear) property with respect to the p_i. The Gini coefficient is in contrast to that linear in the p_i with weighting coefficients depending of the order up to a constant $\sum_{i=0}^{6}(1-p)p_i$ with monotonically increasing p_i. First we consider an empiric connection between Shannon entropy and Gini coefficient looking at 5 year periods. Second we compare the Taylor series to the quadratic term of the function $(1/7+x)\,ln(1/7+x)$:

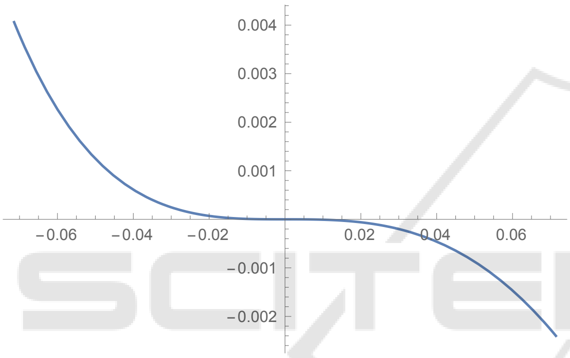

Figure 2: Difference of term in the Shannon sum and its quadratic Taylor series representation.

3 RESULTS

If we use data of the care insurance from 1998-2006, we can consider deviations of the birth rates back to 1905 in Figure 3.
On Saturdays and Sundays we have increased birth rates, lower ones on Tuesdays and Wednesdays. The

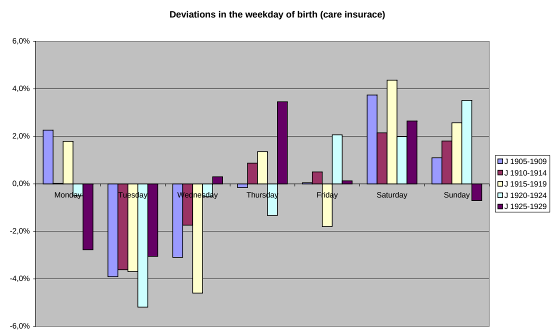

Figure 3: Deviations of birth rates in dependence of the weekday (care insurance data).

other weekdays are somewhere between with instabilities with respect to time periods. One has to take into consideration that only about 20% of the people ever get benefits of care insurance. In contrast to this the great majority of older people gets at least one drug each year. If we use drug prescription data of 2006 we get the distribution of birth rates in Figure 4. There

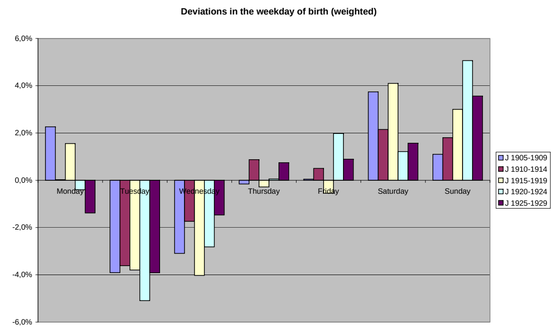

Figure 4: Deviations of birth rates in dependence of the weekday (health insurance data).

are only small differences if we use drug prescription data of 2007 or 2008. At Saturdays the birth rates are less increased compared to care insurance, the rates at Sundays are even larger. The reduced birth rates on Tuesdays and Wednesdays correspond with the results from the care insurance analysis.
If we compare the drug costs of the patients born between 1920 and 1924 with those born between 1925 and 1929 we find an average annual increase of 1.51%. For such considerations it is important to use an age group with monotonously increasing drug costs. Having regard to that we create subgroups with respect to the weekday of birth, cf. Figure 5.

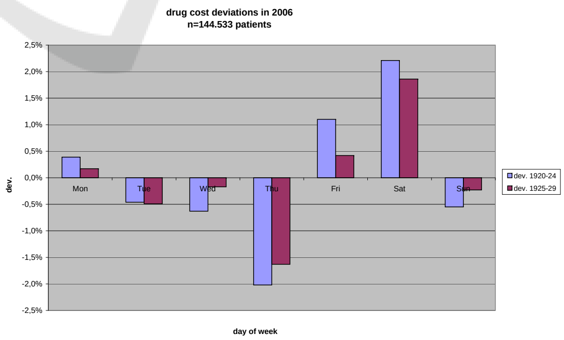

Figure 5: Drug costs in dependence of the weekday of birth for age groups born 1920-24 and 1925-29.

The weekdays with increased and reduced costs do not match those of increased and reduced birth rates. The 1.51% increased drug costs of patients born on Saturdays can be interpreted as having a one year higher biological age than calendar age. On the other hand the people born on Thursdays are one year

younger biologically.
Using the data of care insurance, we find a relevant gender dependent difference in the birth rates on Sundays, cf. Figure 6.

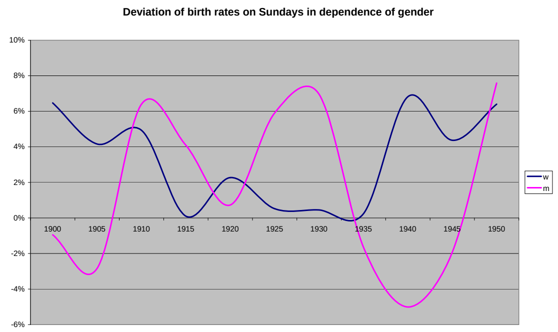

Figure 6: Deviations of the birth rates on Sundays with respect to gender.

Next we consider subgroups with respect to the social status. We use additional payment as a proxy.

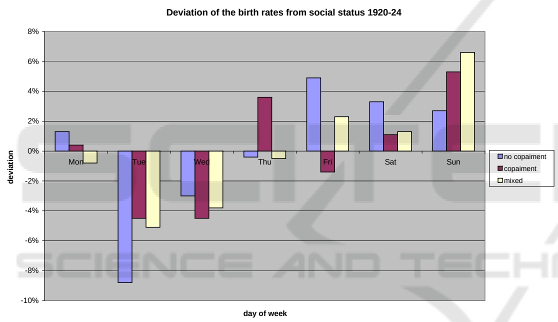

Figure 7: Birth rates in dependence of the social status and the weekday of birth for the period 1920-24.

The group of patients of births for the 1925-29 period and a socially week status show a lower increase in rates on Sundays and higher reduction on Tuesdays, cf. Figure 7 . In the next five year period the situation is quite different, cf. Figure 8.

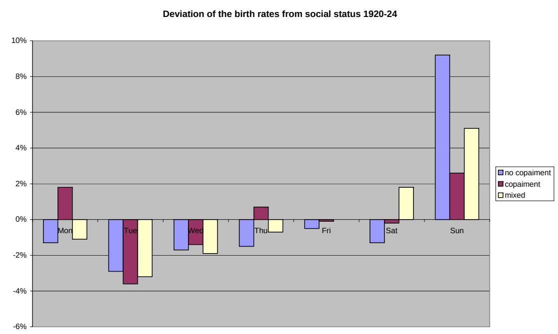

Figure 8: Birth rates in dependence of the social status and the weekday of birth for the period 1925-29.

Social week patients show an even higher increase in birth rates on Sundays but no significant differences in reduced birth rates on Tuesdays. We can compare the rate changes on Thursdays and Sundays directly, cf. Figure 9 and 9.

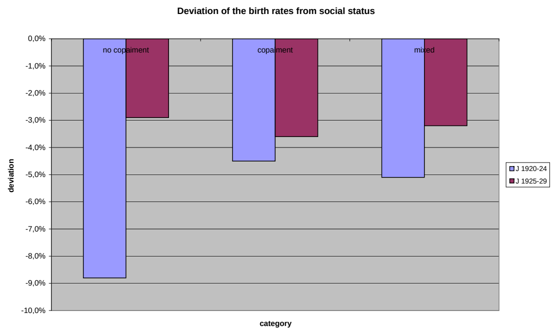

Figure 9: Birth rates on Tuesdays in dependence of the social status in 1920-24 vs. 1925-29.

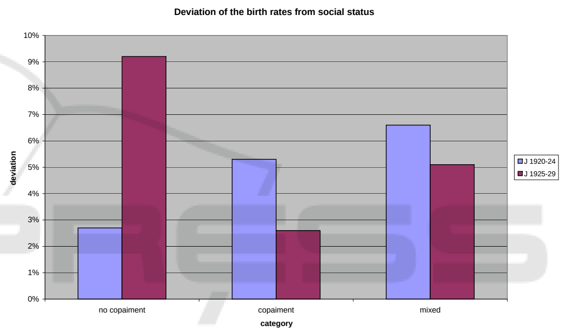

Figure 10: Birth rates on Sundays in dependence of the social status in 1920-24 vs. 1925-29.

Additionally we can use social information using the type of insurance, cf. Figure 11.

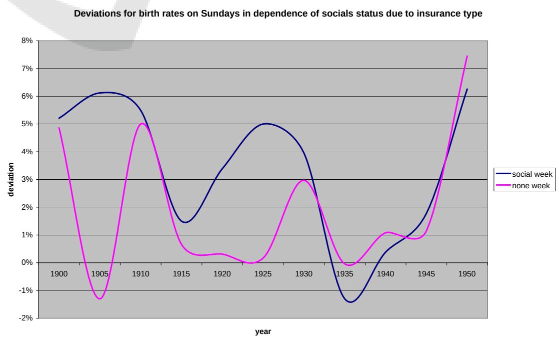

Figure 11: Birth rates on Sundays in dependence of the social status using health insurance type.

We will consider the low risk population and calculate the different fertility rates by the considered quadratic-deviations model with standard deviations 1, 2 and 3 and a limitation of the rate deviations by 20%, cf. Figure 12.

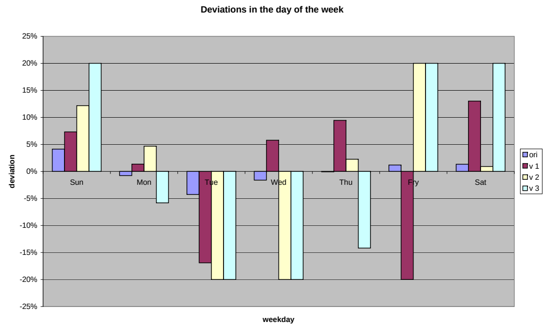

Figure 12: Calculated deviation of the fertility rates with standard deviations 1, 2 and 3.

We see that in general the effects at Saturday and Sundays are increased, the effects at Tuesdays and Wednesdays are reduced. We have used the 20% value in order to limit instabilities. If we would use values from 10% to 25%, we would get the same result for the distribution to the weekdays. Unfortunately we get no further information about a true limit value.
Shannon entropy and Gini coefficients have the same behavior with respect to local maxima and minima. Additionally we can use social information using the type of insurance, cf. Figure 13.

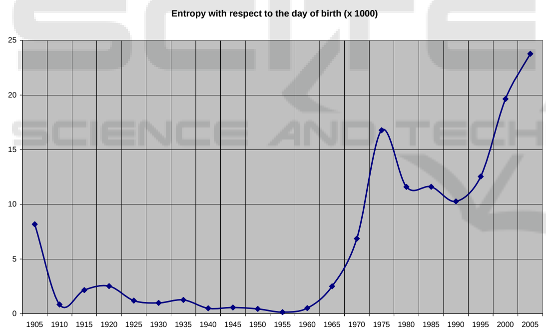

Figure 13: Shannon entropy with respect to the weekdays of birth in dependence of 5 year periods.

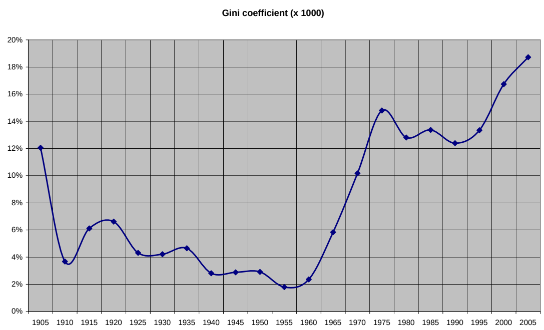

Figure 14: Gini coefficient with respect to the weekdays of birth in dependence of 5 year periods.

Both results show the global minimum for the year 1955. We remember that this year separates the age of increased and that of reduced Sunday birth rates. There is a different resolution between the entropy and the Gini result. The Shannon entropy result uses a nonlinear effect but does not order the used rates, the Gini result is linear but uses ordered rates. Thereby it is interesting that both results coincide so much.
Till now we have considered the weekday period. It is also interesting to consider months.

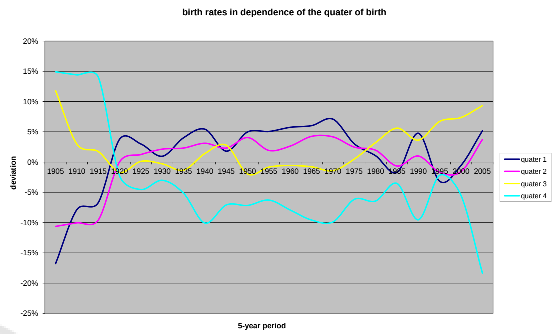

Figure 15: Birth rates in dependence of the quarter of birth.

In 1920-1980 for the first six months there are increased birth rates. Reduced birth dates we have since 1920. Before 1920 the situation is quite different. The mean costs in dependence of the month of birth are quite heterogeneous with respect to different historical periods, cf. Figure 16.

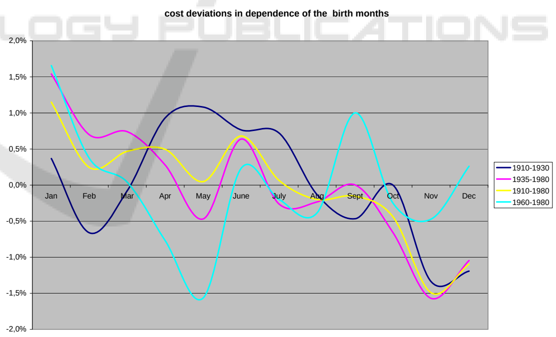

Figure 16: Deviations in drug costs in dependence of the month of birth during different historical periods.

If we consider the period from 1920 till 1980, we have increased costs during the first half of the year and reduced costs during the second half of the year. One explanation could be, that the month of birth has different influences due to the historical period of birth. On the other hand the effect can depend on the age of the persons. We compare the mean effect for birth rates and drug costs from 1920 till 1980 with respect to the quarters of the year, we see that generally increased birth rates and health status measured by drug costs behave reverse, cf. Figure 17.

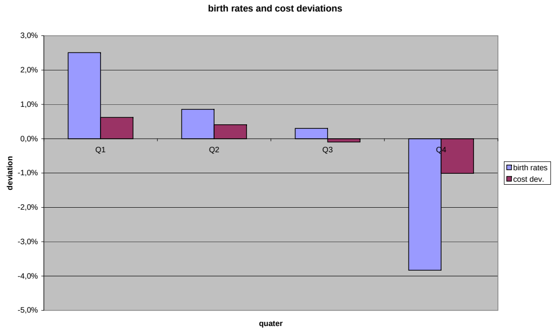

Figure 17: Deviations in birth rates and drug costs with in dependence of the quarters of the year.

Last we compare drug costs in dependence of the quarter of the year for the two groups born from 1910 till 1930 versus the group born between 1960 an 1980, cf. Figure 18.

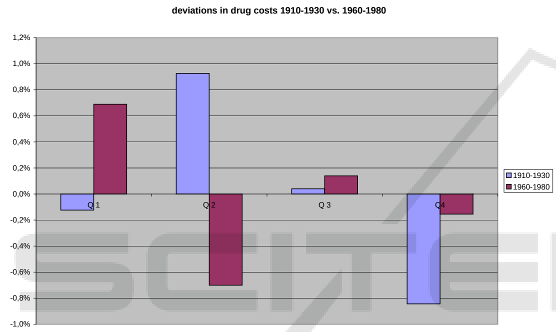

Figure 18: Deviations in drug costs in dependence of the month of birth during different historical periods.

The highest difference we have at quarter two. It can be a consequence of different historical health conditions near to birth. An other explanation would be an age dependent effect.

4 CONCLUSIONS

In order to consider the time between birth and measurements using data of health and care insurance the following statements and guesses can be made regarding the results.
In scenario 1 more births measured in insurance data can be caused by more real births in the considered time 1915-1930. That can be due to different conception and/or fertilization possibilities depending on the day of the week. A bias may be caused by migration.
In scenario 2 the day of birth may causes different survival expectancies in the critical first three days after birth and the related health conditions during these days. That is why we analyze drug costs in dependence of the day of birth. As we already stated, drug costs increase in the mean by 1.5 % per year between the considered two age groups. As a modeling consideration one can use drug costs as a proxy for biological age, comparing it with calendar age. Due to the considered age dependent drug cost increase we can suspect a strong connection to the residual life expectancy. Thursday births around 90 years ago have a one year higher residual life expectancy. Saturday births have a one year lower residual life expectancy, Sunday births have 4 months higher residual life expectancy. In contrast to the situation stated in Macfarlane (1978) lower perinatal mortality rates at weekends can be caused by the fact that quality of care was higher due to family background. In those times specialist obstetric services have been less common compared to later decades. It is quite important, that the psycho-social near birth circumstances 90 years ago may induce significant differences today.

REFERENCES

Kibele, E. U., Jasilionis, D., and Shkolnikov, V. M. (2013). Widening socioeconomic differences in mortality among men aged 65 years and older in Germany. *J Epidemiol Community Health*, 67(1):453–457.

Klein, T., Schneider, S., and Löwel, H. (2001). Bildung und Mortalität. die Bedeutung gesundheitsrelevanter Aspekte des Lebensstils. *Zeitschrift für Soziologie*, 30(5):384–400.

Klein, T. and Unger, R. (2002). Aktive Lebenserwartung in Deutschland und in den USA. *Zeitschrift für Gerontologie und Geriatrie*, 35:528–539.

Lampert, T. and Kroll, L. (2014). Soziale Unterschiede in der Mortalitt und Lebenserwartung. *Hrsg. Robert Koch-Institut, Berlin*, 5(2).

Ma, J., Xu, J., Anderson, R., and Jemal, A. (2012). Widening educational disparities in premature death rates in twenty six states in the United States, 1993-2007. *PloS one*, 7(7).

Macfarlane, A. (1978). Variations in number of births and perinatal mortality by day of week in England and Wales. *British Medical Journal*, 2:1670–1673.

Mackenbach, J. (2006). Health inequalities: Europe in profile. An independent expert report commissioned by the UK Presidency of the EU. *Department of Health, London*.

Mathers, C. (1983). Births and perinatal deaths in Australia: variations by day of week. *Journal of Epidemiology and Community Health*, 37:57–62.

Ostermann, T. and Schuster, R. (2015). An Information-theoretical Approach to Classify Hospitals with Respect to Their Diagnostic Diversity using Shannon's Entropy. *HEALTHINF*.

Schnell, R. and Trappmann, M. (2006). Konsequenzen der Panelmortalitt im SOEP fr Schätzungen der

Lebenserwartung. Arbeitspapier. *Zentrum für Quantitative Methoden und Surveyforschung, Mannheim, Konstanz.*, 2.

Schuster, R. and Emcke, T. (2016). Unterjährige Schwankungen bei den Arzneimittelverschreibungen und bei der Anzahl der Patienten pro Arzt: eine Baseline für den vertragsärztlichen Bereich. *HEC 2016. München*.