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ESTIMATING FLOOD RISKS FOR AUSTRIA, USING A NEIGHBORHOOD RELATION APPROACH

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Abstract

In Austria currently only a relatively small part of losses caused by natural catastrophes is covered by the insurance industry. The majority of financial losses have to be born by the state, i.e. the Austrian Catastrophe Fund. At present, Austria faces discussions about an adequate collaboration between the private insurance market and the public risk transfer (cf. Prettenthaler et al. (2008)). Considering floods, one essential challenge is the appropriate estimation of flood risk. In what follows we will consider losses caused by floods in Austria. We will use the approach from Url (2008) to simulate the distribution of these losses. Furthermore we introduce modified approaches and investigate the sensitivity of the results with respect to these modifications.

1 Introduction

The flood of 2002 in Austria caused a total loss of 2.9 billion Euro, let alone 1.2 billion Euro when not taking into account public losses (c.f. Url (2008)). This event started a discussion of strategies for prevention against the financial impact of such extreme events. The main issue is whether the losses should be born by a Catastrophe Fund set up by the state, or if in the future the losses should be covered by private insurance companies, with the state then only covering losses that exceed a certain high threshold. In both cases it is of prime importance to assess the probability of huge losses and what losses one might expect in the future. The first idea is to use statistical tools which rely on the history of losses caused by floods. With this approach one faces mainly two difficulties. The first one is the small number of observations. For example, if one has 50 data points and one wants to say something about events that occur with probabilities of $1\% - 2\%$, extrapolation methods are needed. These methods always lead to a considerable amount of uncertainty in the estimation. Another source of uncertainty is the change of the structure of the risk over the years. For example, the number and value of buildings that are exposed to flood constantly increased over the last 40 years. Hence statistical methods for estimation can only provide a rough estimate of the future losses and should be complemented by other estimation methods.
In this paper we consider the risk model of Url (2008) which simulates the losses in Austria in a year caused by floods. Besides the implementation of the model as described in Url (2008), we will introduce two modifications to the model and discuss the impact of these modifications to the model. In Secton 2 we describe the model, in Section 3 we give more details on the implementation and in Section 4 we present our numerical results and give a description of the results.

2 The Model

In general, we want to simulate yearly total losses caused by floods in Austria. The first observation is that the estimation of the distribution of the loss of a particular building in a flood event, given its exposure, is a relatively easy task. The idea to obtain the total loss is then to simulate first the number of buildings that are affected by the floods and the strength of the floods. In a second step one simulates the loss of each affected building and hence gets the overall loss.

The basic idea of Url (2008) for the simulation of the number of affected buildings is based on the following observations. Define the annuality of the maximal water gauge in a year of a specific river in a given small area as the expected number of years it takes until a water gauge with the same level or a higher level occurs again. Mathematically this means that the water level of a gauge with annuality $n \geq 1$ is the $(1 - 1/n)$-quantile of the distribution of the water levels and hence the annuality follows a Pareto distribution with $\overline{F}(x) := 1 - F(x) := \mathbb{P}(\text{Annuality} > x) = 1/x$. Let us define that a building of the given area is in a HQ-n zone ($n \in \mathbb{R}^+$) with respect to a river if it is affected by a flood of annuality n (i.e. a flood that is caused by a water gauge of annuality n) or higher. We want to evaluate the number of affected buildings in an area, as a function of the annuality of the flood of this area. Therefor we need that for a given area there is only one river which has only at most one flood event in a year, the area has to be small enough so that we can say that a flood of annuality n always affects the same buildings. Further we have to know the number of buildings in each HQ-n zone. In this case we can simulate the number of affected buildings by simulating the annuality of the flood. If we want to get the total number of buildings that are affected by a flood in a year, we have to add up the number of affected buildings in each area and hence we need to know the joint distribution of the annualities of the floods of all areas, which is a rather tough problem.

A rough approximation of the HQ-n zones is provided by the HORA database, which links every building in Austria to one of the HQ zones HQ-30, HQ-100 or HQ-200. For more details on the HORA database we advice the reader to consult Hora (2006). Since the Hora database is available on a commune basis, it is natural to use the communes as smallest units of areas, although boroughs will not be small enough to ensure the above conditions.

For the implementation of the dependence between the communes, it is assumed in Url (2008) that if a flood affects a certain district, it also affects all districts that are connected to it, under a pre-defined neighborhood condition. This condition shall reflect the spatial correlation between the districts. It is assumed that all communes within an affected district face a flood. At first a global impactfactor of the floods is simulated, the outcome is then used to simulate the annuality for every individual commune. With the knowledge of the relation of the buildings to the HQ zones, we can then simulate the damage for every affected building and finally obtain a total loss as the sum of all single damages. By simulating the total loss for a large number of times (e.g. 1 million times), one obtains an approximation of the distribution of the total loss. We first implement this simulation using the following modules, which are taken from Url (2008). In addition, we then add some alternatives for the modules of Url (2008).

2.1 Module 1 - Simulation of Floods

Module 1 shall simulate the occurrence of floods and return their impact (i.e. the annuality) for all M communes of Austria.

The distance matrix approach This approach is taken from Url (2008). As we are only interested in extreme flood events, we will only consider floods of an annuality of HQ-20 and more. This is equivalent to the assumption that an extreme flood occurs in 5 % on average for every considered district. Extreme flood events usually affect larger areas than only one district. Therefore we assume that in case of a flood in a certain district, this flood also affects its neighboring districts under a specified definition of neighborhood. We start with drawing uniformly distributed random variables x_d with $x_d \sim U[0,1]$ for all districts d (with $d = 1, ..., D$, where D denotes the number of districts in Austria). We then compare the returned values with critical values $cval_d$ given by

$$cval_d = \frac{c \cdot nmng}{nngb_d},$$

where $nmng$ denotes the average number of neighboring districts across Austria, $nngb_d$ denotes the number of neighbors of district d, and c is a constant which shall guarantee an average occurrence of floods in each district of 5%. The latter reflects a flood recurrence of 20 years. We then obtain for all districts d a value ex_d, where $ex_d = 1$ means a flood affects district d and $ex_d = 0$ means that there is no flood:

$$ex_d = \begin{cases} 1 & \text{if } x_d \leq cval_d \text{ or } \exists \text{ a neighbor district } j \neq d \text{ from } d \text{ with } x_j \leq cval_j, \\ 0 & \text{else.} \end{cases}$$

If the simulation returns that none of the districts is affected by a flood, we obtain a total loss of 0 and can skip Module 2 below. Otherwise we have to simulate the annuality of the occurring floods in order to decide how many buildings are indeed affected. Therefore we introduce a random variable $flex$. It shall be drawn from a Pareto distribution and reflect the annuality under the condition that $flex \geq 20$ (we only consider floods with an annuality of 20 or higher), i.e. $\mathbb{P}(flex > x)/20 = 1/x$ for $x \geq 20$. It follows, that the distribution function G of $flex$ is a Pareto distribution (with parameters $\alpha = 1$ and $x_{min} = 20$), given by:

$$G_{flex}(x) = \begin{cases} 0 & \text{if } x < 20 \\ 1 - \frac{20}{x} & \text{if } x \geq 20. \end{cases}$$

Based on the outcome of $flex$ we then obtain the impact of the flood on every affected district d (fld_d) and commune m (flm_m), by adding deviations from a Normal distribution, as

$$fld_d = \begin{cases} flex \cdot |1 + y_d| & \text{if } ex_d = 1 \\ 0 & \text{if } ex_d = 0 \end{cases} \quad \text{and} \quad flm_m = fld_d \cdot |1 + y_m|,$$

respectively, where $y_d \sim N(\mu = 0, \sigma^2 = 0.1)$ and $y_m \sim N(\mu = 0, \sigma^2 = 0.05)$.
Note that the marginal distributions of the annuality in a commune is not Pareto in this approach. From a theoretical point of view this is not optimal.

An alternative copula approach: We want to simulate the annuality for all M communes. We assume that the distribution of the annuality for a specific commune follows a Pareto distribution with $F(x) = 1 - x^{-1}$. This means we have to find the dependence structure of the annuality of the communes. In mathematical terms, this means that we have to specify the copula of the common distribution of the annualities. As an alternative to the distance matrix approach, we will use the copula approach, first defining a specific dependence structure for the annualities, and then simulating from this dependence structure.

2.2 Module 2 - Simulation of Damages

As previously stated, the number of buildings for every commune and HQ zone can be obtained from the HORA database and we assume that this information is available. Additionally to the number of buildings in the HQ zones HQ-30, HQ-100 and HQ-200, we also have the number of buildings outside the HQ-200 zones. In Url (2008) it is assumed that there is an additional HQ zone "HQ-top", which includes all these other buildings beyond HQ-200. Furthermore it is assumed that all buildings would be affected by a flood of annuality 10000, which implies that one can replace HQ-top by HQ-10000.

Linear interpolation As one is interested in the number of buildings in every HQ zone HQ-n (for $n = 1, 2, ..., 10000$), it is suggested in Url (2008) to apply linear interpolation, i.e. to interpolate the number of buildings of HQ-30 for HQ-1,HQ-2,...,HQ-30 (e.g. if we initially considered 120 buildings in HQ-30, we would obtain 4 buildings for every zone HQ-1 to HQ-30 after the interpolation). Subsequently another interpolation is used to obtain the number of buildings of HQ-100 for HQ-31,HQ-32,...,HQ-100, and similarly for HQ-200 and HQ-10000.

Another interpolation method A more flexible interpolation method is to use a linear transformation to map the annualities of a zone to the interval $[0, 1]$, so that the location of each building follows a Beta distribution, with density $f(x|\alpha, \beta) = (1-x)^{\beta-1} x^{\alpha-1} / \mathrm{B}(\alpha, \beta)$. The number of buildings in each zone HQ-n is then given as the expected number of buildings in that zone.

By either of these two methods, we obtain a function $build\_int_m(i)$ for $(i = 1, 2, ..., 10000)$ which returns the number of affected buildings in HQ zone HQ-i for commune m and a given annuality of the flood. We then obtain the actual number of affected buildings nab_m of commune m for a given flood impact flm_m by

$$nab_m = \sum_{i=1}^{\lfloor flm_m \rfloor} build\_int_m(i).$$

We are interested in the number of affected buildings of the HQ zones HQ-30, HQ-100, HQ-200 and HQ-top (HQ-10000) in a given commune m. These numbers are denoted by $nab30$, $nab100$, $nab200$ and $nabtop$, respectively. We obtain

$$nab30_m = \begin{cases} \sum_{i=1}^{B} build\_int_m(i) & B = \min(\lfloor flm_m \rfloor, 30) \\ 0 & \lfloor flm_m \rfloor = 0 \end{cases}$$

$$nab100_m = \begin{cases} \sum_{i=31}^{B} build\_int_m(i) & B = \min(\lfloor flm_m \rfloor, 100), \text{ if } \lfloor flm_m \rfloor > 30 \\ 0 & \text{if } \lfloor flm_m \rfloor \leq 30 \end{cases}$$

$$nab200_m = \begin{cases} \sum_{i=101}^{B} build\_int_m(i) & B = \min(\lfloor flm_m \rfloor, 200), \text{ if } \lfloor flm_m \rfloor > 100 \\ 0 & \text{if } \lfloor flm_m \rfloor \leq 100 \end{cases}$$

$$nabtop_m = \begin{cases} \sum_{i=201}^{B} build\_int_m(i) & B = \min(\lfloor flm_m \rfloor, 10000), \text{ if } \lfloor flm_m \rfloor > 200 \\ 0 & \text{if } \lfloor flm_m \rfloor \leq 200. \end{cases}$$

Up to now we have simulated the number of affected buildings in the zones HQ-30, HQ-100, HQ-200 and HQ-top. We denote the total number of affected buildings in commune m over all HQ zones by $nabtot_m$.

What follows now is the simulation of the degree of damage (the actual loss) for each affected building. It appears that depending on the impact of a flood, only the cellars or upper floors are affected. Thus, it is suggested in Url (2008), that up to an annuality of 100 of a flood (HQ-100) only the cellars are affected, but for floods between HQ-100 and HQ-200 also the upper floors of buildings in the HQ zone HQ-30 suffer damages. For buildings in HQ zone HQ-100, floods of type HQ-200 or higher cause damages in the upper floors as well. We assume that single damages $c_{i,e}$ (where $i = 1, 2, ...$ describes the i-th affected building in a commune) follow a Lognormal distribution with parameters $\zeta_{e,k}$ and $\eta^2_{e,k}$, where k denotes the sector and e the degree of damage (cellar (l - lower loss), or cellar and upper floors (h - higher loss)).

The damage (loss) dab_m in a commune m can then be evaluated by

$$dab_m =$$
$$\begin{cases} \sum_{i=1}^{nbtot_m} c_{i,l} & \text{if } \lfloor flm_m \rfloor \leq 100 \\ \sum_{i=1}^{nab30_m} c_{i,h} + \sum_{i=nab30_m+1}^{nbtot_m} c_{i,l} & \text{if } 100 < \lfloor flm_m \rfloor \leq 200 \\ \sum_{i=1}^{nab30_m+nab100_m} c_{i,h} + \sum_{i=nab30_m+nab100_m+1}^{nabtot_m} c_{i,l} & \text{if } 200 < \lfloor flm_m \rfloor. \end{cases}$$

We finally obtain the total loss as the sum over all communes by

$$dab = \sum_{m=1}^{M} dab_m.$$

3 The Implementation

At first we simulate the flood losses for Austria according to the approach proposed in Url (2008). We will then compare the results with these of the variations of Modules 1 and 2 described above, in order to see what role they play in the simulation of the loss. In Url (2008) the buildings in Austria are split into 5 different sectors (private (residential) buildings, public infrastructure, service sector, industry and trade, and other buildings). In this study we will only consider the sector private buildings, which by far is the largest and hence the most important one. We used the number of buildings in each HQ-zone of each commune from HORA, but one should note that because of protection of privacy these data are not exact.

3.1 Module 1 distance approach

In Url (2008) the distance of two districts is measured as the driving distance between the capital towns of the districts and two districts are neighbors if this distance is less than 100 km. Alternatively in the present study we have estimated the distance between the barycenter points of the individual districts and multiplied these values by 1.5, in order to simulate a distance relationship based on reachability via streets and highways. We now say that two districts are neighbors if this new distance is less than 100 km. We have chosen 1.5 to obtain a constant c in Module 1 of $c = 0.0037$ (cf. Url (2008)). Using these values, simulations have shown that then we can expect around 5% of all districts to be affected by floods on average in a year.

3.2 Module 1 copula approach

We use the following dependence structure for the communes. We assume that the communes of each federal state are conditional independent given a random variable S_{i_m} and that the dependence of the S_{i_m} and flm_m is given by a bivariate Gumbel copula with parameter $\theta^b_{i_m}$ and

$$C_\theta(u,v) = \exp\left(-\left((-\log(u))^\theta + (-\log(u))^\theta\right)^{1/\theta}\right).$$

Further we assume that each federal state i belongs to a region r_i and that the S_i of states in a region are conditional independent given a random variable R_{r_i} and the dependence of the R_{i_m} and S_{r_i} is given by a bivariate Gumbel copula with parameter θ^s_i. The random variables R_r are dependent according to a multivariate Gumbel copula with parameter

State	B	K	NÖ	OÖ	S	ST	T	V	W
state to region	2	2	1	1	1	2	3	3	1
θ^s	1.5	3.5	4	4	4	2.5	3.5	5	9
θ^b	1.5	3.5	5	5	5	3.5	3.5	2	5

Table 1: Parameters for the copula approach

Degree of damage	μ	σ	Lognormal ζ	Lognormal η^2
Cellar	10491	16260.47	8.646043	1.224460
Cellar & floors	24209	36071.62	9.509770	1.169420

Table 2: Parameters for the Lognormal distribution of the damage for single buildings

θ^r. Here we use 3 regions. We used $\theta^r = 2$, and the other parameters can be found in Table 1. Beside these parameters we also used the parameters $\theta^r = \theta_i^s = \theta_i^b = 10$ which corespond to a strong dependence among the communes. Further we used the case when all communes are independent. We assume that there exists a minimal annuality $a_{\min}$, and a flood in a commune only causes damage if it has a greater or equal annuality than $a_{\min}$. In principle, this means that all buildings in HQ-n with $n < a_{\min}$ are assumed to be in HQ-$a_{\min}$ now. If not stated otherwise, we will assume that $a_{\min} = 10$.

3.3 Module 2

Following Url (2008) and Merz et al. (2004) we assume that the single damages of every affected building is random with mean μ and variance σ^2, cf. Table 12 from Url (2008) (in Euro) (originally from Merz et al. (2004) (in DM)). Converting these parameters into parameters ζ and η^2 of a Lognormal distribution, we obtain Table 2.
For Vienna, as stated in Url (2008), we assume other conditions for the occurrence of damages. We assume that up to an annuality of a flood HQ-9800, we do not face any damages, because there are protective barriers preventing such damages. On the other hand, we assume that a flood of HQ-10000 would affect all buildings in Vienna. Within these bounds we assume the number of affected buildings to be linear, and that both cellar and floors suffer damages of all affected buildings.

3.4 Variations of Module 2

For Module 2 we propose the following modifications:

Deterministic damage of buildings: The first possible modification is to use the mean of the lognormal distribution as the damage of a building that is affected by the

Url	Url det.	Copula	Copula det.
112.4	112.6	150.2	150.9

Table 3: Expected total loss for different models in million Euro

flood. This modification is motivated by computational reasons since the sampling of the lognormal distribution is a major part of the computational costs and one wants to know if this part is necessary. In particular in view of the large number of added independent risks, the Strong law of large numbers somehow indicates, that it may be sufficient to consider the expected individual claim size.

Alternative interpolation: Here the buildings in the HQ-30 zone are not linearly interpolated, but we use the alternative interpolation method described in Section 2.2, with $\alpha = 4$ and $\beta = 1.5$.

Vienna is not a special case: Here we just treat Vienna like every other commune.

4 Results and Conclusion

For every model we will use 1000000 realizations of the total loss.
At first we want to compare the model proposed in Url (2008) with the model when we use deterministic damages and to the model with copula dependence among the communes. In Table 3 we provide the expected losses for the 4 different models. The first conclusion is, that the difference between deterministic and non-deterministic damages is negligible (which was to be expected by the law of large numbers). On the other hand we see that the expected losses are quite different if we compare the copula approach with the distance matrix approach. One explanation is that in the copula approach one counts only floods of annuality 10 or higher, whereas in the distance matrix approach in principle one considers only floods with annuality 20 or higher. One should note that the main motivation to use those models is not to get an estimate for the expected total loss but to get an estimate for the tail of the distribution of the total loss, hence we should not overestimate the importance of the expected values. To compare the tails of the distributions, we give the exceedance probabilities for certain thresholds in Table 4. Further we provide the expected total loss for an event of a given annuality in Table 5. At first one should note that the difference between deterministic damages and random damages can be neglected here. If we compare the copula approach with the distance matrix approach we see that the distance matrix approach provides a result that is tighter around the expected value, and hence less risky than the copula approach.
Next we provide examples of different modifications of the copula model. The results can be found in Tables 6, 7, 8, 9 and 10. At first we will consider two different copulas: an

mill Euro	Url	Url det.	Copula	Copula det.
10	35.76 %	35.84 %	48.86 %	48.78 %
50	35.62 %	35.69 %	27.12 %	27.11 %
100	32.56 %	32.62 %	20.28 %	20.3 %
200	20.33 %	20.34 %	14.26 %	14.26 %
300	12.19 %	12.19 %	11.12 %	11.18 %
400	7.59 %	7.57 %	9.15 %	9.22 %
600	3.6 %	3.6 %	6.64 %	6.69 %
800	1.95 %	1.95 %	5.01 %	5.04 %
1000	1.15 %	1.15 %	3.81 %	3.83 %
1500	0.36 %	0.36 %	2.08 %	2.09 %
2000	0.16 %	0.16 %	1.31 %	1.3 %
2500	0.09 %	0.09 %	0.9 %	0.9 %
3000	0.06 %	0.06 %	0.63 %	0.64 %
4000	0.03 %	0.03 %	0.31 %	0.31 %

Table 4: Probability of losses for different models

Annuality	Url	Url det.	Copula	Copula det.
5	203	203	103	103
10	341	341	352	355
20	505	504	801	805
40	715	716	1335	1342
60	856	856	1718	1722
80	968	968	2058	2048
100	1059	1057	2355	2348
150	1225	1229	2926	2933
200	1345	1351	3351	3366
300	1547	1546	3916	3916
500	1840	1852	4560	4592
1000	2405	2423	5604	5615

Table 5: Annualities of losses for different models in million Euro

	Ind	Mon	standard	Equal	Beta	Beta0
with	150.6	151.3	150.2	151.7	115.5	115.6
with out 143.3	144.2	144.1	144.8	107.9	108.3	

Table 6: Expected total loss for different models in million Euro when all buildings can be damaged by floods and when all buildings in HQ-top can not be damaged by floods

independent copula (called Ind) and a highly dependent copula, where, as noted above, all dependent parameters are set to 10. The latter model is called Mon. These two dependence structures are introduced to illustrade, how the chosen copula can change the riskiness of the distribution of the losses. These dependence structures can be seen as a lower or upper limit, respectively for the riskiness.
Further we add two examples, where we use a different distribution for the buildings in the HQ-30 zone. In one case we only considere floods with annuality 10 and higher and in the other case we considere all floods. We refer to these models as Beta and Beta0, respectively. We see that these two models provide similar output. The reason for this is that only a few buildings are located in HQ-n zones with $n < 10$ for these models. If we compare these models to the standard model we see that for smaller annualities (up to 40) the expected loss decreases significantly, whereas the difference for the higher annualities is negligible. At last we use the standard model where we treat also Vienna like the other communes. We denote this model as Equal. One sees that the result of this model is only slightly different with respect to the results of the standard model.
At last we wanted to know what the influence of the HQ-top zone is on the result, so we use the described models with the additional assumption that buildings in HQ-top can not be damaged by floods. We see that in this case only the distribution for losses above 3 billion Euro changes significantly.

4.1 Comparison to reality and discussion of the model

We now want to compare the simulated losses to the history of floods in Austria. At first one should note that in the model proposed by Url (2008) for the simulated data every 5 years there is a flood with a loss of more than 200 million Euros. On the other hand for floods like in 2002 or 1966 (which is believed to have been of similar or even higher strength than the flood of 2002), with a loss exceeding more than 1 billion Euro appear approximately every 100 realizations. This leads to the conclusion that in that model, the probability of medium big floods is overestimated whereas the the probability of huge floods is underestimated. This behavior of the model is unsatisfactory since it leads to an underestimation of the risk. The situation is slightly better for the copula approach. One should note that the parameters where chosen quite randomly, but in such a way that big floods in the Danube area affect the whole states Salzburg, Upper Austria, Lower Austria and Vienna. Of course the results would be more reliable if one would use statistical

mill	Ind	Mon	standard	Equal	Beta	Beta0
10	100. %	16.48 %	48.86 %	48.8 %	35.27 %	36.2 %
50	100. %	13.86 %	27.12 %	27.1 %	18.58 %	18.77 %
100	95.58 %	12.54 %	20.28 %	20.3 %	13.75 %	13.83 %
200	9.97 %	11.05 %	14.26 %	14.27 %	9.72 %	9.74 %
300	0.51 %	10.07 %	11.12 %	11.17 %	7.71 %	7.71 %
400	0.05 %	9.27 %	9.15 %	9.2 %	6.43 %	6.42 %
600	0.01 %	7.9 %	6.64 %	6.69 %	4.83 %	4.8 %
800	0.01 %	6.59 %	5.01 %	5.04 %	3.79 %	3.76 %
1000	0.01 %	5.44 %	3.81 %	3.86 %	3.03 %	2.99 %
1500	0.01 %	3.29 %	2.08 %	2.12 %	1.86 %	1.83 %
2000	0.01 %	1.4 %	1.31 %	1.34 %	1.24 %	1.22 %
2500	0.01 %	1.11 %	0.9 %	0.93 %	0.87 %	0.87 %
3000	0.01 %	0.95 %	0.63 %	0.67 %	0.62 %	0.62 %
4000	0 %	0.64 %	0.31 %	0.33 %	0.3 %	0.31 %

Table 7: Probability of losses for different models when all buildings can be damaged by floods

mill	Ind	Mon	standard	Equal	Beta	Beta0
10	100. %	16.48 %	48.79 %	48.82 %	35.16 %	36.07 %
50	100. %	13.85 %	27.14 %	27.06 %	18.54 %	18.68 %
100	93.03 %	12.54 %	20.35 %	20.26 %	13.74 %	13.77 %
200	7.6 %	11.07 %	14.33 %	14.28 %	9.71 %	9.71 %
300	0.23 %	10.09 %	11.21 %	11.18 %	7.68 %	7.64 %
400	0 %	9.29 %	9.22 %	9.22 %	6.41 %	6.37 %
600	0 %	7.92 %	6.7 %	6.72 %	4.77 %	4.77 %
800	0 %	6.62 %	5.03 %	5.06 %	3.74 %	3.75 %
1000	0 %	5.43 %	3.84 %	3.86 %	2.98 %	3. %
1500	0 %	3.27 %	2.1 %	2.12 %	1.82 %	1.83 %
2000	0 %	1.39 %	1.3 %	1.32 %	1.21 %	1.22 %
2500	0 %	1.12 %	0.89 %	0.9 %	0.84 %	0.84 %
3000	0 %	0.96 %	0.61 %	0.62 %	0.59 %	0.58 %
4000	0 %	0.64 %	0.22 %	0.24 %	0.22 %	0.21 %

Table 8: Probability of losses for different models when all buildings can be damaged by floods when all buildings in HQ-top can not be damaged by floods

mill	Ind	Mon	standard	Equal	Beta	Beta0
5	176	1	103	103	42	43
10	200	309	352	355	190	191
20	224	1087	801	806	573	570
40	248	1658	1335	1348	1182	1167
60	262	1817	1718	1743	1629	1613
80	271	2202	2058	2084	1992	1972
100	278	2833	2355	2396	2309	2291
150	291	3929	2926	3015	2888	2901
200	301	4303	3351	3440	3309	3319
300	314	4686	3916	4001	3870	3894
500	333	5051	4560	4704	4578	4552
1000	365	5934	5604	5767	5621	5567

Table 9: Annualities of losses for different models in million Euro when all buildings can be damaged by floods

mill	Ind	Mon	standard	Equal	Beta	Beta0
5	168	1	104	103	42	43
10	191	310	356	356	190	189
20	214	1083	805	809	567	564
40	236	1657	1347	1355	1163	1172
60	249	1815	1720	1744	1604	1613
80	257	2200	2049	2071	1960	1962
100	263	2872	2337	2357	2264	2266
150	274	3939	2884	2914	2827	2816
200	281	4276	3229	3276	3204	3201
300	291	4497	3679	3719	3652	3637
500	304	4526	4054	4120	4057	4043
1000	321	4542	4314	4388	4316	4312

Table 10: Annualities of losses for different models in million Euro when all buildings in HQ-top can not be damaged by floods

studies to determine the dependence structure of the communes, but one has to accept that deriving a more than 2000-dimensional distribution by only statistical methods is not realistic.

We now want to discuss how the model can be made more realistic. If we look at the simulation results it seems that the crucial quantity in the simulation is the number of buildings that are affected and in which zone they are. On the other hand the distribution of the individual loss of buildings is so important and one can operate with expected values instead of distributions. To get the number of the affected buildings, we have in principle to fulfill two tasks. The first is to get a realistic vector of the annuality of the flood of each commune. As noted above this is a rather tough task. The second problem of the model is the inaccuracy of the HQ-Zones. For example the most buildings are in the Zones HQ-30 and HQ-Top, but there is little known about the distribution of the buildings inside the classes, further the accuracy of the meaning of HQ-30 is not too good. Further, as noted in Url (2008) the influence of protective structures is not considered in HORA satisfactorily. This may lead to an overestimation of the flood risk. For a realistic model it is important to improve on these two points.

At last one should ask the question if it is a good idea to use the annualities of each commune as the determining source of randomness. From a practical point of view it would be preferable to first simulate the maximal water gauge of a year for each river, and then deduce the flood-affected areas and buildings for that year (similarly to what is done in the HORA study). Of course one should note that in this case one still has the problem to find the joint distribution of the water gauges. On the other hand such a model would be more reliable than working with annualities. A study that uses such an approach for the German case is the HQ-Kumul project of the Gesamtverband der Deutschen Versicherungswirtschaft (GDV) (compare Kron & Ellenrieder (2008)).

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