Anonymous Referee #3

1) General comments

The paper "Uncertainty and Sensitivity Analyses in Seismic Risk Assessments on the Example of Cologne, Germany" by Tyagunov et al., focuses at methodological aspects of considering aleatory and epistemic uncertainties in seismic risk assessments. The topic is certainly timely and the methods used are appropriate for the problem at hand. Nevertheless, I have some minor criticisms that the authors should consider to improve their discussion about handling epistemic uncertainties (see specific comments). My main concern is in the implication of assuming both -the original input data/models and models/data drawn from other sources- as equally uncertain for the Cologne case.

Beyond the sensitivity analysis and considering the large uncertainty bounds obtained in the results, I think that the paper would benefit of assessing also the effects of the choice of the weights assigned to the branches.

Therefore, comparing the results obtained assuming equal weights with results assuming more informative, knowledge-based weights (i.e. better reflecting the knowledge that the authors have about the models/data used), would be an important element for discussing the uncertainty assessment following the implemented logic tree approach.

2) Specific comments

The authors implement a logic tree approach as a tool for analysing epistemic uncertainties associated with the parameters and models used in the hazard and risk analyses. However, regarding the uncertainty analysis, my main concern is about the ground assumption done by the authors, assuming that the original input data and models are as equally uncertain as the data and models drawn from other sources (p. 7297, Lines 17-19). This choice, that implies assigning equal weights to all the branches of the logic tree (e.g. p. 7299, Lines 6-10), is argued as a realistic situation in little-studied areas lacking reliable regional data.

My criticism regarding this point is that this choice may produce misleading uncertainty 'bounds' in the example used in the paper (Cologne), where specifically developed models and data are available. I think that assigning equal weights to all the branches of the logic tree in this example should be better discussed and argued by the authors, since I would suspect that those models and data available for the area could be considered as more 'informative' (for the case under analysis) than other models/data borrowed from other regions. In other cases, high resolution models may bear more detailed information that other with lower resolution. Therefore, if we know or can expect that some models perform better that others, why not providing a higher weight to them? This in fact, may better reflect the knowledge you have of the used data.

I agree with the authors that this choice may hold in little studied areas but, for a case as the discussed example, I would wonder: Is the 'equal-weights' choice a way of rejecting a piece of 'known' information that eventually may contribute reducing epistemic uncertainties? I think this point is important for the

discussion because epistemic uncertainties are the key topic of the paper. Some examples of alternative branches where one can wonder for the arguments to assume equal weights are:

a) In the seismic hazard modelling: using data, on one hand, form the Stromeyer and Gurnthal (2009) and Grunthal et al (2010) models for Central Europe, and on the other hand the model of Chandler and Lam (2002) for a region in China (p. 7298, L. 15-25);

b) In the modelling of the existing building stock: using two models with quite different levels of detail and resolution. On one hand, VM1 represents the whole city as one cell and is pointed out as an approach for studies over regional or national scales and for rough estimations of risk (p. 7300, L. 20-25); on the other hand, VM2 follows the approach of Wieland et al. (2012), where the territory is divided into a grid of cells that are relatively homogeneous in terms of their predominant building types (p. 7301, L. 10-15). Therefore, a high resolution against a low resolution model.

c) In the loss modelling: On one hand, LM1 is based on the damage classification of EMS98 and considered consistent with the European building typology; on the other hand, LM2 more appropriate for the building typology in the USA (p. 7305, L. 1-10). In this case, LM1 is likely more adequate for the problem, whereas giving the same weight to LM2 in probably just introducing unnecessary noise.

d) Somehow, also in the uncertainties of some parameters: in particular, the Mmax. In this case, a +-0.5 value respect to the original max. magnitude estimated by Grunthal et al 2010 is assumed (and therefore, a distance of 1.0M units between them). Note that the resulting Mmax values are not coming from different 'competing' models arriving to different values, but arbitrary bounds assigned as a plus/minus range around a single value. Therefore, I wonder about the implications of using equal weights in this case, since these two bounds may be orders of magnitude different.

3) References

Stromeyer, D. and Grünthal, G.: Attenuation relationship of macroseismic intensities in Central Europe, B. Seismol. Soc. Am., 99, 554–565, 2009.

Grünthal, G., Arvidsson, R., and Bosse, C.: Earthquake Model for the European–Mediterranean Region for the Purpose of GEM1, Scientific Technical Report SRT10/04, GFZ, 36, 2010.

Chandler, A. M. and Lam, N. T. K.: Intensity attenuation relationship for the South China region and comparison with the component attenuation model, J. Asian Earth Sci., 20, 775–790, 2002.

Wieland, M., Pittore, M., Parolai, S., Zschau, J., Moldobekov, B., and Begaliev, U.: Estimating building inventory for rapid seismic vulnerability assessment: towards an integrated approach based on multi-source imaging, Soil Dyn. Earthq. Eng., 36, 70–83, 2012.

Dear Anonymous Referee,

Thank you for the positive response and thoughtful comments. Please find our answers below.

You are absolutely right emphasizing the importance of weights assigned to different branches in the logic tree approach. Certainly, we aware that properly assigned knowledge-based weights would reduce the total uncertainty bounds in the calculated results. At the same time we should keep in mind that the distribution of weights also represents a considerable source of uncertainty, which, in turn, may be misleading and critical for decision making especially in little-studied areas.

As indicated in the title, this particular study is not "for Cologne", rather "on the example of Cologne". We have stated in the introductory part of the paper that this study does not aim to revise or refine the earlier (mean-based) estimates of the seismic risk for the city, rather to attract attention to the problem of existing uncertainties, which have not been taken into account in the earlier seismic risk studies for the area. At the same time, the principal goal of this study is to consider the problem from the point of view of less well studied areas, where researchers lack reliable information related to every component of risk modeling, including hazard, vulnerability, and exposure. Unfortunately, this is a quite realistic state of affairs in many parts of the world. Therefore, on the example of Cologne (using the data available for the area and results of the previous studies as a benchmark, that gives us a possibility of comparing mean estimates for the purpose of illustration) we are approaching a more common problem of epistemic uncertainty and sensitivity analysis in seismic risk calculations.

Certainly, we agree with your specific comments regarding the comparison of weights for different logic tree branches, in particular, that the preference (higher weight) should be given to the models based on the regional data (your comments "a" and "c") in comparison with the data adapted from other regions. If the goal of the study would be calculating risk for Cologne (or any other specific case), then of course we would do the calculations in such a way. However, we intentionally introduce the uncertainties purposing to simulate a typical situation in little studied areas. And, moreover, we avoid inventing any hypothetical models, instead we employ the existing models available in publications, e.g. for hazard modelling (along with the available regional IPE of Stromeyer and Grünthal, 2009) we introduce uncertainty using the model of Chandler and Lam (2002) developed for similar tectonic conditions in China and the model of Allen and Wald (2010) developed for global applications. Similarly, for loss modelling along with the loss model (LM1) of Tyagunov et al (2006a), which obviously is more reasonable for the case of Cologne, we introduce additional uncertainty using the model (LM2) of Hwang et al (2004). At the same time, again referring to the lack of knowledge in the context of little studied areas, we intentionally use equal weights for all the branches. In our opinion, such an approach provides a clear illustration of dangerous pitfalls associated with using the models adapted from other regions, which may introduce a considerable uncertainty to the calculated results.

Regarding the specific comment "b", we agree that, in general, one should favor a high resolution against a low resolution model. However, in the considered case the advantage of high resolution data consists mainly in the spatial distribution of exposure around the area of the city, while in the risk calculations the both vulnerability composition models VM1 and VM2 represent the whole city as one cell. Therefore, we use the equal weights for both vulnerability branches.

As for the specific comment "d", definitely, the maximum possible magnitude is one of the main factors determining the seismic risk estimation and therefore a special attention should be paid to this input

parameter. Unfortunately, at the current state of knowledge there is still considerable uncertainty in estimating this key parameter even in well-studied areas. In our opinion the interval of about 1.0M units (and even higher) may realistically represent existing uncertainty in little studied areas. Therefore we decided to assign equal weights for the different branches.

We very much appreciate the raised important points concerning the problem of assigning weights to different branches in the logic tree approach. We have updated the discussion part of the paper (in particular, Sections 11 and 12) taking into account all the written above:

Update 1 (Section 11)

"…the uncertainty bounds shown in Fig. 13 should not be regarded as a quantitative estimation for the specific case of Cologne, rather for the illustration purposes in the context of less well studied areas".

Update 2 (Section 12)

"The use of regional knowledge-based information for assigning weights to the different models (branches of the logic tree) would reduce the total uncertainty in the calculated results.

In the end it is important to note once again, that in this study on the example of Cologne along with the original data available for the area we intentionally used models adapted from other regions with equal weights for both the regional and adapted models, keeping in mind the lack of knowledge in the context of less well studied areas. The resulting therefrom uncertainty bounds should not be regarded as a quantitative estimation of uncertainty for the specific case of Cologne that was not the goal of the study".

We hope these small but meaningful updates will make the concept of the paper and the results more transparent and understandable for the readers.

Many thanks.