climada module **country risk** 27 Jan 2015

https://github.com/davidnbresch/climada_module_country_risk
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This module runs all (available) perils for one country[1]. It generates earthquake (EQ), tropical cyclone (TC), torrential rain (TR) and storm surge (TS) hazard event sets, checks for European winter storm (WS) exposure and runs all risk calculations for a given country (see option for any state/province or admin1 further below).

Further, the module calculates the economic loss (i.e. the full range of economic costs in the wake of a natural disaster) associated with the hazard event sets[2].

Function reference (use `help` to get a detailed description and input/output specification):

`country_risk_calc`: generate assets and hazard sets for a given country (i.e. admin0, or a list of countries). A convenient way to get started for any given country.

`country_admin1_risk_calc`: Once `country_risk_calc` has been run for a country (or a series of), calculate the admin1 (state/province) level results

`climada_nightlight_entity`: Generate the (high-resolution) asset distribution for any country (admin0) and any state/province (admin1) within.

`cr_economic_loss_calc`: given (property damage) output from `country_risk_calc`, calculate total economic loss

`country_risk_report`: produce a report given output from either `country_risk_calc` or `cr_economic_loss_calc` (see also `cr_loss_multiplier_plot`)

`climada_EDS_emdat_adjust`: given an event damage set, adjust such that it matches best the EM-DAT damage history of a given country and hazard (see also `emdat_read`)

Also useful (in core climada)

`climada_entity_value_GDP_adjust`: given an entity with assets for a country, adjust total asset value to represent country assets (a simple formula based on GDP and country development index)

Basic procedure implemented in `country_risk_calc` is as follows:

1) generate centroids for the country (uses `climada_create_GDP_entity`[3] or `climada_nightlight_entity`)
2) figure which hazards affect the country
3) create the hazard event sets, using
   - climada_tc_hazard_set (tropical cyclone wind[4])
   - climada_tr_hazard_set (tropical cyclone rain[5])
   - climada_ts_hazard_set (tropical cyclone surge[6])

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[1] See further below for `country_admin1_risk_calc`, which runs the calculation for one state/province in a given country. The routine climada_country_risk also allows for processing a list or even all countries. As always, use `help climada_country_risk` to get a detailed description on the options.

[2] See appendix for details on the calculation of economic loss based on the damages in the hazard event set.

[3] See https://github.com/davidnbresch/climada_module_GDP_entity and further below for `climada_nightlight_entity` which allows to generate a high-resolution entity for any country and state/province.

[4] Core climada contains the basic tropical cyclone hazard, but please add the module https://github.com/davidnbresch/climada_module_tc_hazard_advanced to generate useful probabilistic hazard event sets (see parameter `probabilistic` in `country_risk_calc`). Please consider to run `climada_tc_get_unisys_databases` (climada core) in order to download the latest tropical cyclone databases for all ocean basins (core climate comes with TC Atlantic to start with).

[5] See climada module https://github.com/davidnbresch/climada_module_tc_rain

- eq_global_hazard_set (earthquake[7])
- European winter storm (hazard not generated, just assigned[8])

4) run the risk calculation for all hazards
5) run the economic loss calculation for all hazards

In essence, you define the country and the code runs the generation of centroids, default assets (from nightlight intensity, see climada module GDP_entity) and the EQ, TC, TR and TS hazard event sets plus checks for WS Europe exposure. It even figures whether the country is exposed to more than one ocean basin and in such a case generates a suite of TC/TS/TR hazard event sets for each ocean basin. The code is ready for upgrade with additional hazards (usually a new hazard is a new climada module). That's why the code notifies the user if the specific hazard module is missing (even indicates the github location where to get it from).

Simply call e.g. `country_risk_calc('El Salvador')`
If called without any argument, a list dialog to select the country pops up. See code header for details, i.e. **`help country_risk_calc`**

Behind the scenes, the code `centroids_generate_hazard_sets` does the heavy lifting, i.e. steps 2) and 3) from above. This way one can generate all relevant hazard sets with one call to `centroids_generate_hazard_sets` for any set of centroids (e.g. only a part of a country, a region, a city…[9]):

```
centroids_hazard_info=...
   centroids_generate_hazard_sets(centroids,force_recalc,check_plots)
```

The resulting structure `centroids_hazard_info` contains the names of the generated hazard sets (or the ones generated earlier if just called to check for step 2) in `centroids_hazard_info.res.hazard(i).hazard_set_file` (the somewhat complicated nested structure is due to the flexibility required by `country_risk_calc`).

[6] See climada module https://github.com/davidnbresch/climada_module_tc_surge which also requires the module https://github.com/davidnbresch/climada_module_etopo
[7] See climada module https://github.com/davidnbresch/climada_module_eq_global
[8] See climada module for European winter storm, which contains the hazard sets https://github.com/davidnbresch/climada_module_ws_europe
[9] See e.g. the code `climada_cut_out_GDP_entity` from https://github.com/davidnbresch/climada_module_GDP_entity and also `country_admin1_risk_calc` and `climada_nightlight_entity` further below (part of module country risk)

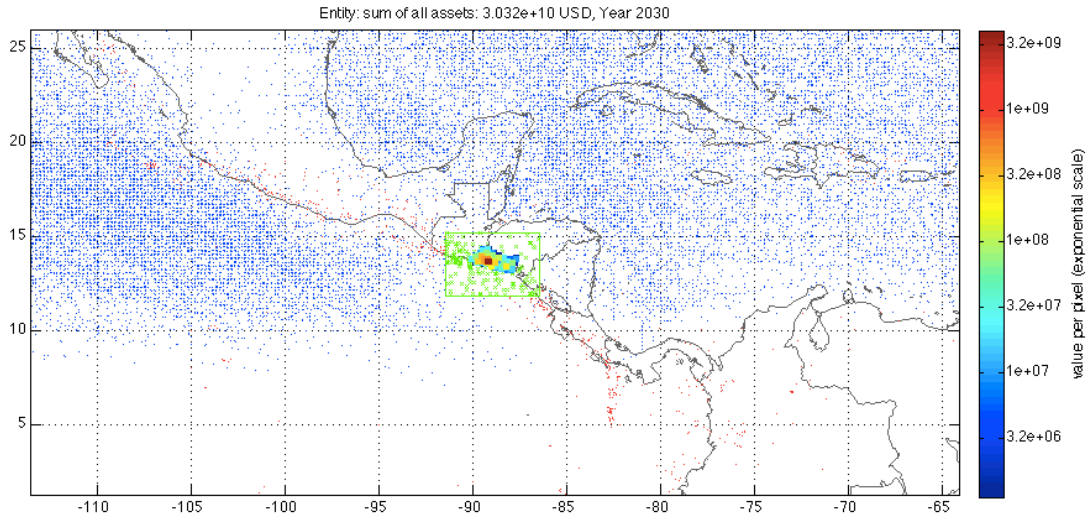

Figure: Step 1 (generate centroids, assets distribution, color scale indicates value per centroid) and step 2 (hazard selection). The green box shows the selection area around the country, the blue dots are all the TC track nodes (historic) and the red dots the epicenters (historic). This figure is generated if check_plot=1 in the call, e.g. `country_risk_calc('El Salvador',0,0,1)`.

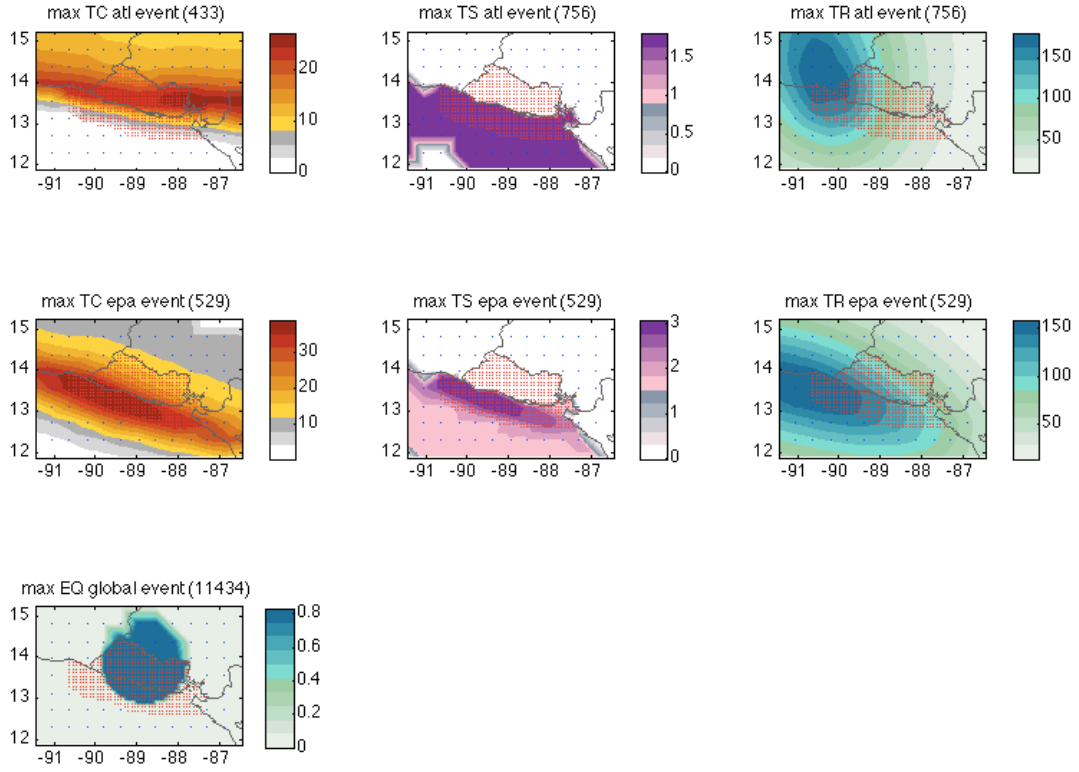

Figure: The most intense single event for all hazard generated for El Salvador (Step 3). Note that El Salvador is both exposed to tropical cyclones from the East and West, that's why there are two hazard events sets for TC/TS/TR, one for the Atlantic side (atl for Atlantic), one for the Pacific side (epa for East Pacific Ocean). The earthquake model is global. Note further the nice feature of hazard (or peril) – dependent color scales; and the coarser resolution of centroids (blue) around the country (with red dots at high-density centroids) to support plotting hazard

intensities around the country, too. This figure is generated if `check_plot=1` in the call, e.g. `country_risk_calc('El Salvador',0,0,1)`

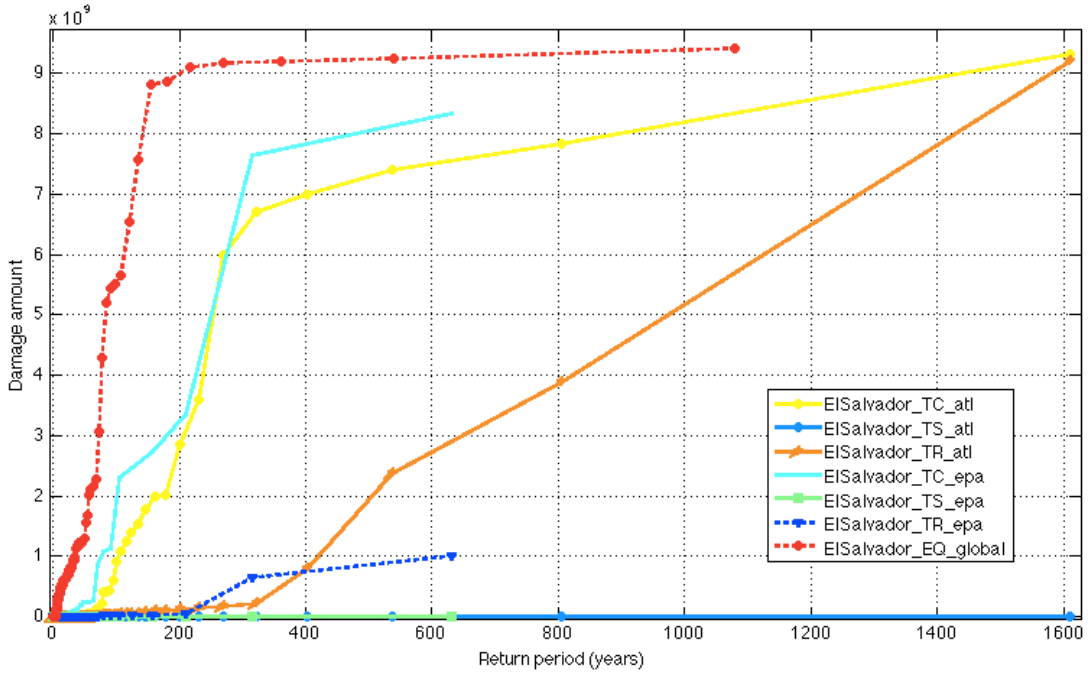

Figure: The resulting damage frequency curves (DFC) for all seven (!) hazards affecting El Salvador (values just for illustration, based on dummy damage functions). This figure is generated with check_plot=1 in the call, e.g. `country_risk_report(country_risk_calc('El Salvador',1,1),0,1)`

`cr_economic_loss_calc:` Major natural disasters can and do have severe negative short-run economic impacts, the severity of which depends on the affected country's resilience, or ability to recover. `cr_economic_loss_calc` calculates the economic damages resulting from the simple property damages in the hazard event set, taking into account socio-economic data on the country's financial strength, supply chain risk profile, resilience and preparedness for natural disasters (see appendix for details).

`country_risk_report`: Comes in handy if one runs some select countries, e.g:

```
country_risk=country_risk_calc('Barbados')
country_risk(2)=country_risk_calc('El Salvador')
country_risk(3)=country_risk_calc('Costa Rica')
```

And then `country_risk_report(country_risk,0)` results in the following output (to stdout, also an Excel or .csv file is written[10]):

```
Barbados (1)
  TR EL=36572051.496470       (8.481508%o)          Barbados_TR_atl
  TC EL=23083330.494007       (5.353308%o)          Barbados_TC_atl
  TS EL=7531.966739           (0.001747%o)          Barbados_TS_atl
  EQ EL=0.000000              (0.000000%o)          Barbados_EQ_global
ElSalvador (2)
  EQ EL=415631535.361110      (17.943889%o)         ElSalvador_EQ_global
  TR EL=141613002.072040      (6.113800%o)          ElSalvador_TR_epa
  TC EL=59386249.565168       (2.563858%o)          ElSalvador_TC_atl
  TC EL=16152772.894979       (0.697357%o)          ElSalvador_TC_epa
  TR EL=621784.438763         (0.026844%o)          ElSalvador_TR_atl
  TS EL=0.000000              (0.000000%o)          ElSalvador_TS_epa
  TS EL=0.000000              (0.000000%o)          ElSalvador_TS_atl
Costa Rica (3)
  EQ EL=523833928.441207      (12.396559%o)         Costa Rica_EQ_global
  TR EL=1530537.767294        (0.036220%o)          Costa Rica_TR_epa
  TC EL=73978.520263          (0.001751%o)          Costa Rica_TC_epa
  TR EL=5765.009179           (0.000136%o)          Costa Rica_TR_atl
  TS EL=1689.347413           (0.000040%o)          Costa Rica_TS_atl
  TC EL=60.830655             (0.000001%o)          Costa Rica_TC_atl
  TS EL=0.000000              (0.000000%o)          Costa Rica_TS_epa
```

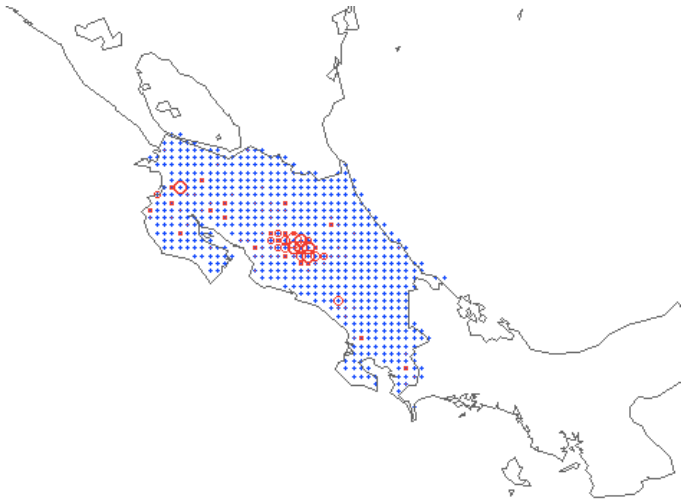

Figure: The local damage for a given peril (here EQ) for one country (here Costa Rica) in spatial resolution (e.g. at each centroid). Produced by the call (following from above resulting structure `country_risk`):

```
country_i=3; hazard_i=7[11];
climada_circle_plot(...
country_risk(country_i).res.hazard(hazard_i).EDS.ED_at_centroid,...
country_risk(country_i).res.hazard(hazard_i).EDS.assets.Longitude,...
country_risk(country_i).res.hazard(hazard_i).EDS.assets.Latitude)
```

[10] The report does contain the annual expected damage (ED) as well as defined return periods (such as 100 and 250 years). In case writing an Excel file fails, a .csv file is written.

[11] Note that the number seven here corresponds to the 7th hazard analyzed (EQ). The report to stdout shows EQ as the first result, since `country_risk_report` sorts by descending damage, unless it is called with the second parameter (`print_unsorted`) set to 1.

`country_admin1_risk_calc`: Same as country_risk_calc, but for a state or province (admin1 level) of any given country. Run the all (available) perils for one country's admin1 level. Obtain the admin1 boundaries (from www.naturalearthdata.com, shape files already part of the data that comes with the country risk module) and carve out the respective centroids (set Value at all others to zero). Run the risk calculation for each admin1 for all hazards. In case one would like to skip hazards, just (temporarily) remove the respective {country_name}_*.mat hazard event sets. ONLY makes sense if country_risk_calc has been run for the respective country (we keep it like this, as automatic mode might trigger lots of un-wanted calculations). If not, the code terminates with the respective messages (no entity found, no hazard set(s) found...). But one can run country_admin1_risk_calc for more than one country, if the respective countries have been run as country_risk_calc. NOTE: Before using this code, make yourself familiar with country_risk_calc and country_risk_report (same format as country_risk_calc).

`climada_nightlight_entity`: Construct an entity file based on high-res (1km!) night light data[12]. Reads an image file with nightlight density[13] and matches it to the local geography. Prompts for country (admin0) and state/province (admin1), constrains the active centroids (with values>0) to the selected country or admin1 and saves the entity. Since we're dealing with admin1, no automatic scaling or allocation of GDP to centroids is performed (for this, see climada_create_GDP_entity[14]).

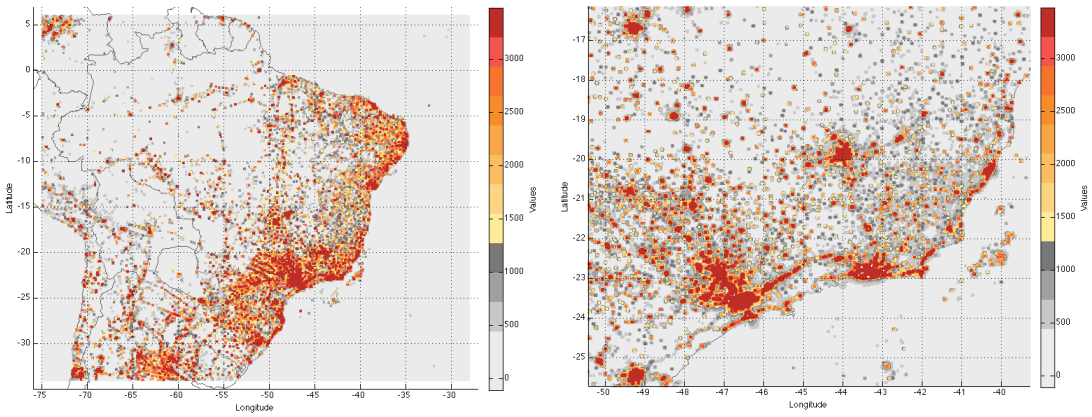

Figure: Brazil value distribution on 1km (!) resolution (left, zoomed in right) as generated by `climada_nightlight_entity('Brazil','',2)`

[12] One can also run it at moderate (10x10km) resolution, see parameter selections, i.e. type `help climada_highres_entity`

[13] The climada module country_risk comes with the .mat file F182012.v4c_web.stable_lights.avg_vis.mat (24MB), since the .tif image is about 700MB. See http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html#AVSLCFC3 to obtain the file http://ngdc.noaa.gov/eog/data/web_data/v4composites/F182012.v4.tar and unzip the file F182012.v4c_web.stable_lights.avg_vis.tif in there to the /data folder of country_risk module. As the .tif is so much larger, the climada module country_risk comes with the .mat file, but does not contain the original (.tif). Should the .mat file not exist, climada_nightlight_entity creates it on first call. Please note that the GDP_entity could also deal with such a high-res dataset (see respective documentation).

[14] See footnote 8 above

Appendix

A. Calculation of economic damage in `cr_economic_loss_calc`

Starting point for the economic loss calculation is damage(event_i), i.e. the property damage calculated by climada_EDS_calc. The economic loss then also includes secondary losses to an economy including e.g. lost ouput, retail sales, wages, costs to business form rerouting goods and services around the affected area, reduced taxable receipts, etc.
The underlying rationale of the calculation is that a property damage resulting from a natural disaster does not have a major impact on a country's economy as long as the damage is small compared to the country's GDP, and as long as adequate financing and national resources exist. However, if a damage is big, it will be exacerbated depending on how well a country is "in shape" to deal with major shocks.

`cr_economic_loss_calc` intends to estimate the economic damage as it manifests itself about 3-6 months after a disaster occurred. This first-round effect of natural disasters is usually that income and output (GDP) fall. What happens in the next round then depends on the way the country or region responds to the crisis. For example, Japan is a strong economy and has the resources to start rebuilding quickly, while smaller and badly managed countries such as Haiti can suffer severe long-term effects. It should be noted that `cr_economic_loss_calc` only calculates the temporary dip following the first months after a disaster (see Figure).
After that initial dip, different scenarios can lead to no, positive or negative follow-on effects over the long run. In particular, a natural disaster can even positively affect total factor productivity, e.g. when it leads to the replacement of damaged, outdated production facilities and physical infrastructure with state-of-the-art facilities and infrastructure. However, as noted above, `cr_economic_loss_calc` only deals with the calculation of the initial impact, not with the long-term scenarios.

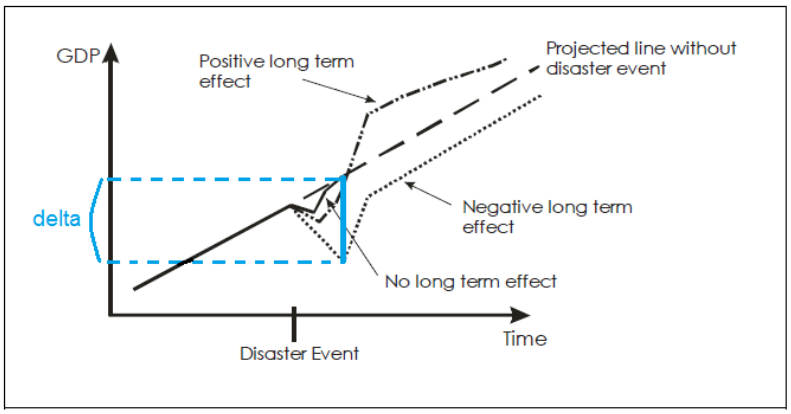

Figure: Possible trajectories of GDP after a disaster[15]. The delta is the initial temporary dip `cr_economic_loss_calc` provides an estimate for.

[15] Source: Hochrainer, 2006
https://openknowledge.worldbank.org/bitstream/handle/10986/4162/WPS4968.pdf?sequence=1

In `cr_economic_loss_calc`, the economic loss caused by the natural disaster is calculated according to:

```
economic_loss(event_i) = damage(event_i) * loss_multiplier
```

where loss_multiplier is defined by:

```
loss_multiplier =
1 + cr_get_damage_weight(damage(event_i)/GDP) * country_damage_factor
```

with:

`cr_get_damage_weight`: function that determines how much weight a damage should be given based on its ratio to GDP

```
country_damage_factor = 1/financial_strength ...
                      + BI_and_supply_chain_risk ...
                      + natural_hazard_economic_exposure ...
                      - disaster_resilience
```

Hence, `country_damage_factor` consists of four terms:

- `financial_strength` measures a country's economic health and ability to finance the recovery.

```
financial_strength = total_reserves/GDP ...
                   + insurance_penetration ...
                   + income_group ...
                   - central_government_debt
```

- `BI_and_supply_chain_risk` measures a country's risk of disaster-related business and supply chain interruption

```
BI_and_supply_chain_risk = GDP_industry ...
                         + FM_resilience_index_supply_chain/100
```

- `natural_hazard_economic_exposure` assesses which countries have a concentration of their total economic output exposed to natural hazards

```
natural_hazard_economic_exposure = ...
                  1 - Natural_Hazards_Economic_Exposure/10
```

- `disaster_resilience` measures the quality of a country's natural hazard risk management, i.e., the country's "preparedness" to deal with the consequences of a disaster

```
disaster_resilience = FM_resilience_index_risk_quality/100 ...
                    + (global_competitiveness_index-1)/6
```

See economic_indicators_mastertable.xls (in the data folder of the country_risk module[16]) for more information on the four components of country_damage_factor (and their respective subcomponents).

[16] Download: https://github.com/davidnbresch/climada_module_country_risk