Survival Modeling

In this notebook we will develop "survival models". These will be mathematical devices to (in the next notebook) evaluate our current existential risk situation.

What I want to achieve with these existential risk/survival models, is to estimate a civilization's life-span, as a function of current risk levels, and based on it's handling of these risks.

```
# Imports
import matplotlib.pyplot as plt
import numpy as np
import seaborn as srs
import pandas as pd
from matplotlib.ticker import FuncFormatter
import time
import pprint

from the_extinction_game.models.single_risk_binary_tree import build_xrisk_tree, estimate_si
from the_extinction_game.models.disjoint_events_constant_risk import DisjoinEventsConstantRi
from the_extinction_game.reporting import plot_survival_analysis
from the_extinction_game.models.multi_risk_binary_tree import MultiRiskBinaryTreeModel
from the_extinction_game.experiment import Experiment

# Setup seaborn
srs.set_theme()
```

The Extinction Game

The basis for developing the survival models in this notebook is what I call *The Extinction Game*.

We start with basic models, and then proceed to make them progressively more complex, allowing us to model more complex dynamics, like the change of X-Risk through the centuries, and making successive Extinction Games dependent.

So what is the Extinction Game?

It's a game that the virtual civilizations' - whose fate we're trying to capture in a mathematical model - play once every century. The game has two possible outcomes:

- The civilization survives and goes on to play again in the next century, or
- it looses, and doesn't get to play again

We're not going to go into the details of what it means to *win* or *loose* the game, that'll be a subject for later, which involves a more philosophical discussion. In this notebook, we'll focus on the more technical and mathematical aspects.

We'll devise the following survival models:

- ☒ Disjoint events with constant risk
- ☒ Single risk binary tree with constant risk change
- ☒ Multi risk binary tree with constant risk change
- ☐ Multi risk binary tree with risk change correlations
- ☐ Multi risk binary tree with asymmetric risk change

Let's get to it!

Disjoint Events with Constant Total Risk

This is the simplest model. In it, humanity's existential risk is modeled as a probability cascade, where the extinction game is played every century, and every century is independent - meaning that the outcome in one century doesn't affect the game in other centuries. We also use a constant figure for total risk.

Though this model has the downside of modeling each century as independent - which they're arguably not - it could serve as a "business as usual" scenario, where risk levels are maintained, reflecting a lack of effort to actively reduce them, or just enough effort to not let them increase.

To describe the problem we introduce the following events and expressions:

- E: Extinction in a randomly chosen century
- E_n: Extinction after n centuries
- S: Survival in a randomly chosen century
- S_n: Survival after n centuries
- $P(E)$: Probability of extinction in a randomly chosen century
- $P(S)$: Probability of survival in a randomly chosen century
- $P(E_n)$: Probability of extinction after n centuries
- $P(S_n)$: Probability of survival after n centuries

We can establish the relationships between $P(E)$, $P(S)$, $P(E_n)$, and $P(S_n)$.

First we assume that $P(S)$ and $P(E)$ are complementary and mutually exclusive. Either there is or isn't an extinction event in a randomly chosen century. And similarly, after n centuries, either there has been or there hasn't been an extinction event, so $P(E_n)$, and $P(S_n)$ are also mutually exclusive and complementary.

$$P(S) = 1 - P(E)$$
$$P(S_n) = 1 - P(E_n)$$

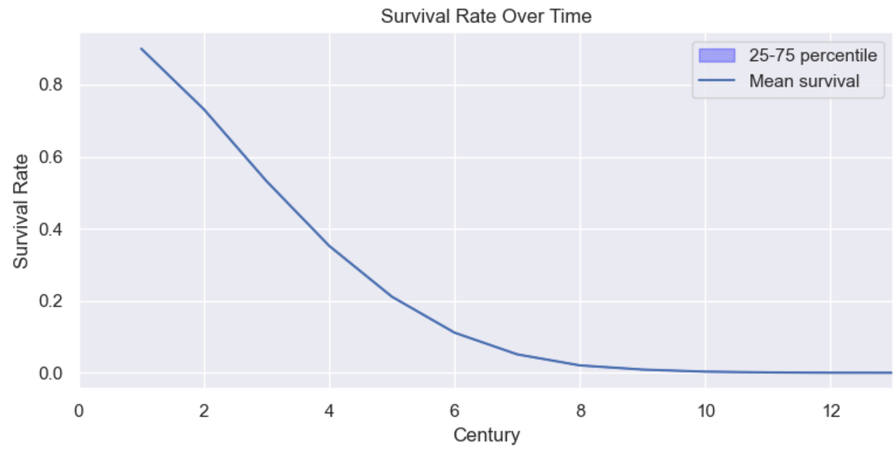
To model the survival probability after n centuries, we can just multiply the survival probability n times, or raise it to the power of n:

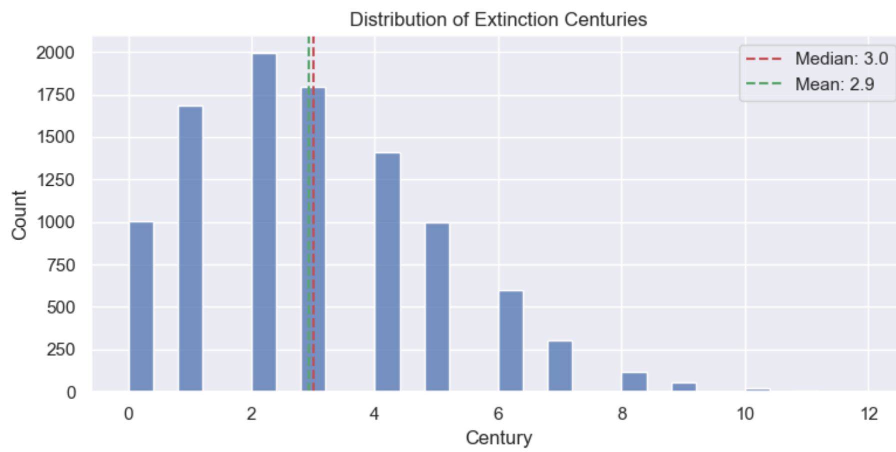
$$P(S_n) = P(S)^n$$
$$P(S_n) = [1 - P(E)]^n$$

The expression $P(S_n)$ tells us then that the probability of survival after n centuries is the complementary existential risk $(1 - P(E))$ raised to the power of n.

We've now modeled the survival probability in a very simple way. Let's see how this model behaves.

```
model = DisjoinEventsConstantRiskModel(1000, 0.1)
experiment = Experiment(model, n_simulations=10000)

survival, extinction_centuries = experiment.run()

stats, survival_by_century = experiment.get_stats()

fig, axes = plt.subplots(2, 1, figsize=(8, 8))
ax = experiment.plot_survival_rate(ax=axes[0])
latest_extinction = stats['latest_extinction'].max()
ax.set_xlim([0, latest_extinction + 1])

ax_hist = experiment.plot_extinction_century_histogram(ax=axes[1])
```


Survival Rate Over Time
25-75 percentile
Mean survival
Survival Rate
0.0
0.2
0.4
0.6
0.8
0
2
4
6
8
10
12
Century


Distribution of Extinction Centuries
Median: 3.0
Mean: 2.9
Count
0
250
500
750
1000
1250
1500
1750
2000
0
2
4
6
8
10
12
Century