analysis

October 22, 2025

Data Description We recommend that you number the months, with the earliest starting at zero (0). The last month of the time window is month eleven (11), which is also the current period, i.e., the present, for the most part of this.

- **cohort** is the group of customers that was acquired in each month. For example, a user belongs to cohort 3 if s/he was acquired in month 3 (i.e., the 4th month).
- **user** identifies the different users.
- **time_year** is the year and time_month is the month
- **subscription** is binary (1–0) variable that takes on the value one (1) if the user had an (active) subscription at the time. This variable is always one (1) because we cannot observe the behavior of users after they cancel their subscription or after they switch to a device other than their desktop and laptop computers. For the assignment, we define that a user churns if s/he stops watching Netflix online, i.e., because s/he cancels the subscription or switches to a different device.
- **content** is the number of different titles (e.g., shows and movies) that a user consumed in a month.
- **genres** is the number of different genres that are associated with a user's monthly Netflix consumption. This variable has a missing value if the user did not use Netflix in a particular month.
- **recency** is the share of recent content that a user watched in a month. The streaming of a title is recent if the time between the title's release date and the date of the stream is less than two years

0.1 Data Loading and Cleaning

[107]:
```
import pandas as pd
import datetime as dt
import matplotlib.pyplot as plt

# Load data and ensure 'user' is treated as string; drop rows without a user id
data = pd.read_csv("data.csv")
data = data.dropna(subset=['user'])
data['user'] = data['user'].astype(str).str.strip()
data = data[data['user'] != '']

# Create a robust 'date' column from time_year and time_month (day set to 1)
data['time_year'] = pd.to_numeric(data.get('time_year', None), errors='coerce')
```

```python
data['time_month'] = pd.to_numeric(data.get('time_month', None),␣
 ↪errors='coerce')
data['date'] = pd.to_datetime(
    data['time_year'].fillna(0).astype(int).astype(str) + '-' +
    data['time_month'].fillna(1).astype(int).astype(str) + '-01',
    errors='coerce'
)
# drop rows with invalid date
data = data.dropna(subset=['date'])
# create a monthly period column for grouping
data['period'] = data['date'].dt.to_period('M')

# Quick checks
data.info()
data.describe(include='all')
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 34475 entries, 0 to 34474
Data columns (total 11 columns):
 #   Column        Non-Null Count  Dtype
---  ------        --------------  -----
 0   cohort        34475 non-null  int64
 1   user          34475 non-null  object
 2   time_year     34475 non-null  int64
 3   time_month    34475 non-null  int64
 4   subscription  34475 non-null  int64
 5   content       34059 non-null  float64
 6   genres        34059 non-null  float64
 7   recency_new   34059 non-null  float64
 8   bounce        34059 non-null  float64
 9   date          34475 non-null  datetime64[ns]
 10  period        34475 non-null  period[M]
dtypes: datetime64[ns](1), float64(4), int64(4), object(1), period[M](1)
memory usage: 2.9+ MB
```

[107]:

```
              cohort   user     time_year    time_month  subscription  \
count   34475.000000  34475  34475.000000  34475.000000       34475.0
unique           NaN  21440           NaN           NaN           NaN
top              NaN   1291           NaN           NaN           NaN
freq             NaN     12           NaN           NaN           NaN
mean        5.396461    NaN   2017.380595      6.294329           1.0
min         0.000000    NaN   2017.000000      1.000000           1.0
25%         2.000000    NaN   2017.000000      3.000000           1.0
50%         6.000000    NaN   2017.000000      6.000000           1.0
75%         8.000000    NaN   2018.000000      9.000000           1.0
max        11.000000    NaN   2018.000000     12.000000           1.0
std         3.453917    NaN      0.485540      3.534924           0.0
```

```
             content        genres   recency_new        bounce  \
count   34059.000000  34059.000000  34059.000000  34059.000000
unique           NaN           NaN           NaN           NaN
top              NaN           NaN           NaN           NaN
freq             NaN           NaN           NaN           NaN
mean        3.873249      1.885258      0.371159      0.449736
min         1.000000      1.000000      0.000000      0.000000
25%         2.000000      1.000000      0.000000      0.000000
50%         3.000000      2.000000      0.333300      0.500000
75%         5.000000      2.000000      0.636400      0.692300
max        81.000000      5.000000      1.000000      1.000000
std         3.892327      0.951980      0.355709      0.354376

                                 date   period
count                           34475    34475
unique                            NaN       12
top                               NaN  2018-02
freq                              NaN     3400
mean    2017-10-27 04:39:51.298041856      NaN
min               2017-05-01 00:00:00      NaN
25%               2017-08-01 00:00:00      NaN
50%               2017-11-01 00:00:00      NaN
75%               2018-02-01 00:00:00      NaN
max               2018-04-01 00:00:00      NaN
std                               NaN      NaN
```

- Total number of unique users
- New users per month
- Active users per month
- Churned users per month
- Retention rate per month
- Average expected lifetime (in months)
- Distribution summary (% of users active after 3 months, 6 etc)
- Survival Probabilities

0.2 Total number of unique users

[108]:
```
# Total unique users in dataset
unique_users = data['user'].nunique()

print("Total unique users:" , unique_users)
```

```
Total unique users: 21440
```

0.3 New users per month (cohort)

[109]:
```python
# New users per cohort
#( 'cohort' represents acquisition month

# remove duplicates and then  count per cohort
new_users = data.drop_duplicates(subset=['user']).groupby('cohort')['user'].
 ↪nunique().sort_index()

print("Total new users per cohort: ")
print(new_users)
```

```
Total new users per cohort:
cohort
0      1791
1      2120
2      1268
3      1788
4      1367
5      1761
6      1806
7      1565
8      1967
9      2066
10     1602
11     2339
Name: user, dtype: int64
```

0.4 Active Users per month

[110]:
```python
# Active users per month using 'period' and 'content' >= 1
active_users = (
    data[ data['content'].fillna(0) >= 1 ]
    .groupby('period')['user']
    .nunique()
    .sort_index()
)
print(active_users)
```

```
period
2017-05    1791
2017-06    3152
2017-07    2817
2017-08    2643
2017-09    2528
2017-10    2464
2017-11    2647
2017-12    3040
```

```
2018-01    3201
2018-02    3361
2018-03    3144
2018-04    3271
Freq: M, Name: user, dtype: int64
```

0.5 Churned and retained users per month

[111]:
```python
# Calcolo churn + retention per period usando 'date'/'period' (fix creazione␣
↪'date')
import numpy as np

# Non ricaricare data se già presente; assicurati che time_year/time_month␣
↪siano numerici
data['time_year'] = pd.to_numeric(data.get('time_year'), errors='coerce')
data['time_month'] = pd.to_numeric(data.get('time_month'), errors='coerce')

# Crea colonna 'date' in modo robusto: usa solo righe con year e month validi
valid = data['time_year'].notna() & data['time_month'].notna()
if valid.any():
    data.loc[valid, 'date'] = pd.to_datetime({
        'year': data.loc[valid, 'time_year'].astype(int),
        'month': data.loc[valid, 'time_month'].astype(int),
        'day': 1
    }, errors='coerce')

data = data.dropna(subset=['date'])  # rimuovi righe senza data valida
data['period'] = data['date'].dt.to_period('M')

# Serie: per ogni period gli user con subscription==1 (array di user unici)
subscribed_by_period = (
    data[data['subscription'] == 1]
    .groupby('period')['user']
    .unique()
    .sort_index()
)

# Itera sui period effettivamente presenti e usa period + 1 (gestisce anno)
periods = list(subscribed_by_period.index.sort_values())
rows = []
for p in periods:
    curr = set(subscribed_by_period.loc[p])
    total = len(curr)
    next_p = p + 1  # pandas.Period addition: aggiunge un mese e gestisce␣
↪cambio anno
    if next_p in subscribed_by_period.index:
        nxt = set(subscribed_by_period.loc[next_p])
```

```
        retained = len(curr & nxt)
        churned = len(curr - nxt)
        retention_rate = retained / total if total > 0 else np.nan
        churn_rate = churned / total if total > 0 else np.nan
    else:
        # se non abbiamo dati per il mese successivo non stimiamo retention/
 ↪churn
        retained = np.nan
        churned = np.nan
        retention_rate = np.nan
        churn_rate = np.nan
    rows.append({
        'period': p,
        'total_users': total,
        'retained_users': retained,
        'churned_users': churned,
        'retention_rate': retention_rate,
        'churn_rate': churn_rate
    })

churn_dataframe = pd.DataFrame(rows).set_index('period').sort_index()

# Aggiungi nome mese per leggibilità (es: 'January')
month_names =␣
 ↪['January','February','March','April','May','June','July','August','September','October','N
churn_dataframe['month_name'] = [month_names[p.to_timestamp().month - 1] for p␣
 ↪in churn_dataframe.index]

print('Churn/retention calcolati usando period + 1 month (gestito anno).')
print(churn_dataframe)
```

```
Churn/retention calcolati usando period + 1 month (gestito anno).
         total_users  retained_users  churned_users  retention_rate  \
period
2017-05         1791          1055.0          736.0        0.589056
2017-06         3175          1597.0         1578.0        0.502992
2017-07         2865           908.0         1957.0        0.316928
2017-08         2696          1190.0         1506.0        0.441395
2017-09         2557           732.0         1825.0        0.286273
2017-10         2493           890.0         1603.0        0.357000
2017-11         2696          1516.0         1180.0        0.562315
2017-12         3081          1265.0         1816.0        0.410581
2018-01         3232          1334.0         1898.0        0.412748
2018-02         3400          1588.0         1812.0        0.467059
2018-03         3190           960.0         2230.0        0.300940
2018-04         3299             NaN            NaN             NaN
```

```
         churn_rate month_name
period
2017-05    0.410944        May
2017-06    0.497008       June
2017-07    0.683072       July
2017-08    0.558605     August
2017-09    0.713727  September
2017-10    0.643000    October
2017-11    0.437685   November
2017-12    0.589419   December
2018-01    0.587252    January
2018-02    0.532941   February
2018-03    0.699060      March
2018-04         NaN      April
```

0.6 Average Expected Lifetime

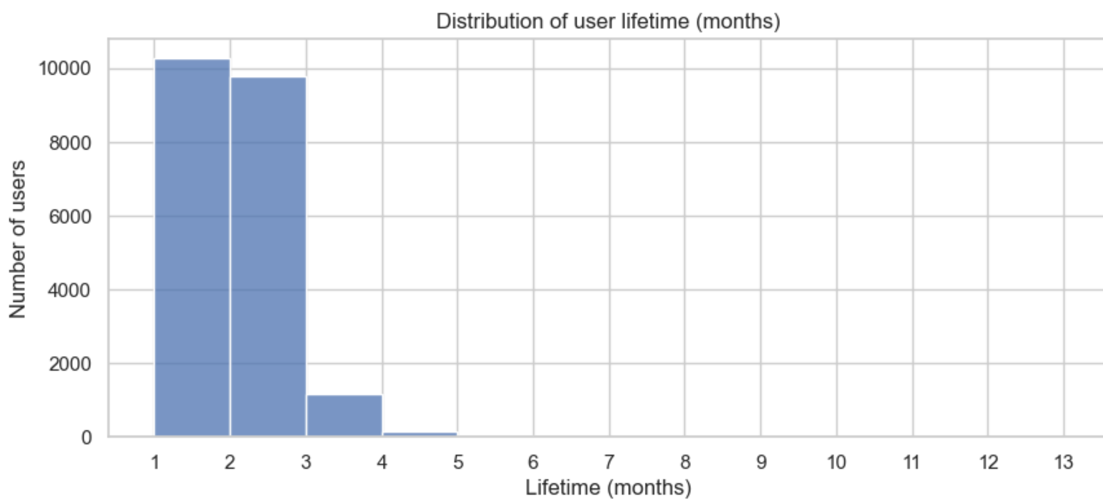
average expted lifetime calculated as last month of activity per user - first month of activity.

key assumption: the user does not return after the last observed month.

[112]:
```python
# Compute average observed lifetime (months) using Period subtraction to handle␣
↪year changes
import matplotlib.pyplot as plt
import seaborn as sns
sns.set(style='whitegrid')

# use cleaned dataframe 'data' with 'date' column
df = data.dropna(subset=['user','date']).copy()
df['period'] = df['date'].dt.to_period('M')

# primo e ultimo period osservato per user
first_period = df.groupby('user')['date'].min()
last_period = df.groupby('user')['date'].max()


lifetime_months = (last_period.dt.year - first_period.dt.year) * 12 +␣
↪(last_period.dt.month - first_period.dt.month) + 1

# lifetime in months: difference tra period (gestisce cambio anno) +1 per␣
↪includere il mese iniziale
#lifetime_months = (last_period - first_period) + 1
#lifetime_months = lifetime_months.clip(lower=0)

average_lifetime = lifetime_months.mean()
median_lifetime = lifetime_months.median()
print('Average lifetime (months):', average_lifetime)
print('Median lifetime (months):', median_lifetime)
```

```
# Plot histogram
max_life = int(lifetime_months.dropna().max()) if not lifetime_months.dropna().
↪empty else 1
bins = range(1, max_life + 2)
plt.figure(figsize=(10,4))
sns.histplot(lifetime_months.dropna(), bins=bins, kde=False)
plt.title('Distribution of user lifetime (months)')
plt.xlabel('Lifetime (months)')
plt.ylabel('Number of users')
plt.xticks(bins)
plt.show()
```

```
Average lifetime (months): 1.6079757462686568
Median lifetime (months): 2.0
```



0.7 Quick script to see users with longer lifetime

edit the "threshold" variable and set the number of days. the script return the users with a lifetime bigger than that.

[113]:
```
lifetime = (last_period - first_period) + pd.Timedelta(days=31)

threshold = 100

filtered_users = lifetime[lifetime >= pd.Timedelta(days=threshold)]
filtered_users
```

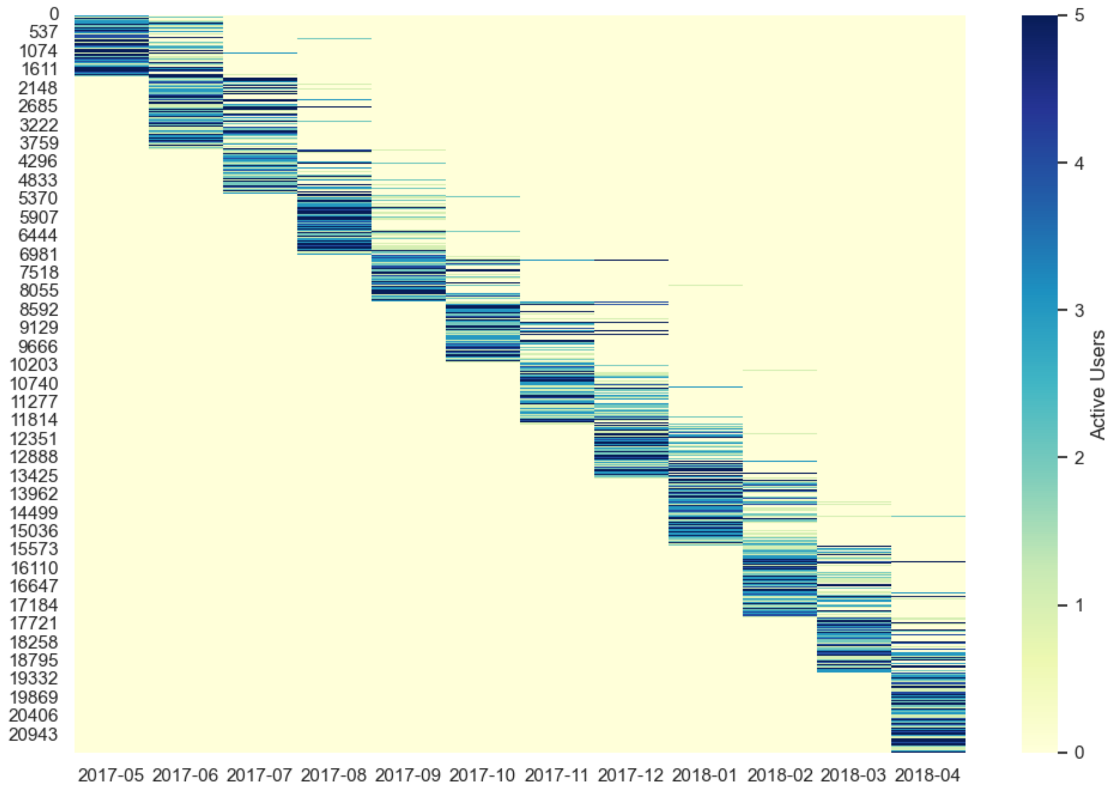
[113]:
```
user
10272   123 days
```

```
10326   123 days
10334   151 days
10369   182 days
10370   182 days
          …
961     366 days
9853    213 days
9910    123 days
9922    123 days
9984    123 days
Name: date, Length: 234, dtype: timedelta64[ns]
```

0.8 Content for user plot

[114]:
```
users = data['user'].unique()
periods = data['period'].unique()

content_matrix_dataframe = pd.DataFrame(index=users, columns=periods)

for user in users:
    user_data = data[data['user'] == user]
    for period in periods:
        period_data = user_data[user_data['period'] == period]
        if not period_data.empty:
            content_value = period_data['content'].iloc[0]
            content_matrix_dataframe.at[user, period] = content_value


content_matrix_dataframe = content_matrix_dataframe.fillna(0)
```

[115]:
```
import seaborn as sns
import matplotlib.pyplot as plt

# Assuming active_users_matrix is your data
plt.figure(figsize=(12, 8))  # Increased dimensions: width=12, height=8
sns.heatmap(content_matrix_dataframe, cmap='YlGnBu', cbar_kws={'label': 'Active␣
↪Users'}, vmin=0, vmax=5)

plt.show()
```



0.9 Distribution Summary

[116]:
```python
# Build binary active_users_matrix: 1 se content >= 1 in quel period, 0␣
↪altrimenti
df_active = data.copy()
df_active['active'] = (df_active['content'].fillna(0) >= 1).astype(int)
df_active = df_active[['user','period','active']].drop_duplicates()

# pivot in matrix (user x period) con valori 1/0
active_users_matrix = (
    df_active.pivot_table(index='user', columns='period', values='active',␣
↪aggfunc='max')
    .fillna(0).astype(int)
)

print('Active users matrix built: rows=users, cols=periods')
print(active_users_matrix.shape)
```

```
Active users matrix built: rows=users, cols=periods
(21440, 12)
```

[117]:

```python
# From active_users_matrix compute % of users still active after k months since␣
↪first activation (k=1..12)
import numpy as np

# ensure columns are PeriodIndex
cols = active_users_matrix.columns

# find first active period per user (NaT if never active)
def first_active_period(row):
    active_cols = [c for c, v in row.items() if int(v) == 1]
    return active_cols[0] if active_cols else pd.NaT

first_active = active_users_matrix.apply(first_active_period, axis=1)

users = active_users_matrix.index.tolist()
n_users = len(users)

rows = []
for k in range(1, 13):
    active_count = 0
    for u in users:
        fa = first_active.loc[u]
        if pd.isna(fa):
            continue
        target = fa + k  # Period + int aggiunge mesi correttamente
        if target in active_users_matrix.columns:
            if active_users_matrix.at[u, target] == 1:
                active_count += 1
        # se target non esiste, l'utente non è considerato attivo per quel k
    pct = (active_count / n_users * 100) if n_users > 0 else np.nan
    rows.append({'months_after_first_activation': k, 'active_count':␣
↪int(active_count), 'active_pct': pct})

distribution_k = pd.DataFrame(rows).set_index('months_after_first_activation')
print('Percent of users active after k months since first activation:')

# keep results for later use
distribution_k
```

```
Percent of users active after k months since first activation:
```

[117]:

	active_count	active_pct
months_after_first_activation		
1	10910	50.886194
2	1311	6.114739
3	202	0.942164
4	75	0.349813

5	43	0.200560
6	28	0.130597
7	18	0.083955
8	11	0.051306
9	6	0.027985
10	8	0.037313
11	8	0.037313
12	0	0.000000

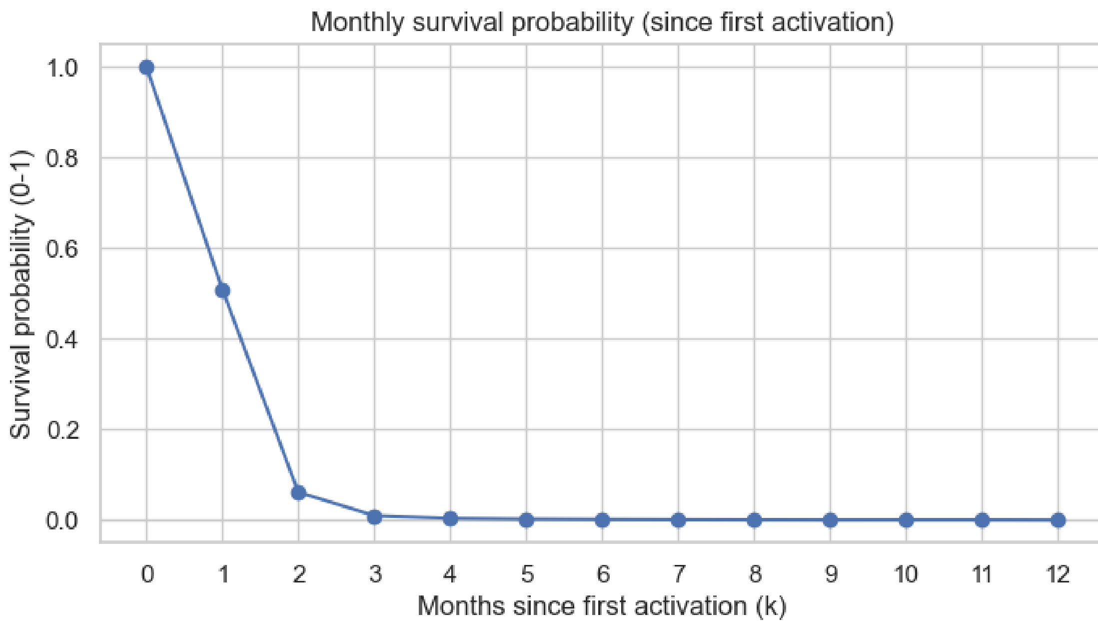
0.10 Monthly Survival Probability

[118]:

```
# Monthly survival probabilities (k = 0..12) since first activation
import numpy as np
import matplotlib.pyplot as plt

# Binary active table: active = content >= 1
df_active = data.copy()
df_active['active'] = (df_active['content'].fillna(0) >= 1).astype(int)
df_active = df_active[df_active['active'] == 1][['user','period']].
↪drop_duplicates()

# First active period per user
first_active = df_active.groupby('user')['period'].min()
users = first_active.index.to_numpy()
n_users = len(users)

rows = []
for k in range(0, 13):
    # target period per user (Period + int aggiunge mesi correttamente e␣
↪gestisce cambio anno)
    target_periods = (first_active + k).reindex(users)
    left = pd.DataFrame({'user': users, 'target_period': target_periods.values})
    # merge per verificare attività in target_period
    merged = left.merge(df_active, left_on=['user','target_period'],␣
↪right_on=['user','period'], how='left', indicator=True)
    active_count = int((merged['_merge'] == 'both').sum())
    survival_prob = active_count / n_users if n_users > 0 else np.nan
    rows.append({
        'k': k,
        'active_count': active_count,
        'survival_prob': survival_prob,
        'survival_pct': survival_prob * 100 if not np.isnan(survival_prob) else␣
↪np.nan
    })

survival_df = pd.DataFrame(rows).set_index('k')
# Conditional month-to-month retention
```

```python
survival_df['conditional_retention'] = survival_df['survival_prob'] /␣
↪survival_df['survival_prob'].shift(1)

print('Monthly survival probabilities (k = months since first activation):')
print(survival_df)

# Plot survival curve
plt.figure(figsize=(8,4))
plt.plot(survival_df.index, survival_df['survival_prob'], marker='o')
plt.title('Monthly survival probability (since first activation)')
plt.xlabel('Months since first activation (k)')
plt.ylabel('Survival probability (0-1)')
plt.xticks(survival_df.index)
plt.grid(True)
plt.show()

# expose survival_df for downstream analysis
survival_df
```

```
Monthly survival probabilities (k = months since first activation):
    active_count  survival_prob  survival_pct  conditional_retention
k
0          21439       1.000000    100.000000                    NaN
1          10910       0.508886     50.888568               0.508886
2           1311       0.061150      6.115024               0.120165
3            202       0.009422      0.942208               0.154081
4             75       0.003498      0.349830               0.371287
5             43       0.002006      0.200569               0.573333
6             28       0.001306      0.130603               0.651163
7             18       0.000840      0.083959               0.642857
8             11       0.000513      0.051308               0.611111
9              6       0.000280      0.027986               0.545455
10             8       0.000373      0.037315               1.333333
11             8       0.000373      0.037315               1.000000
12             0       0.000000      0.000000               0.000000
```



[118]:

k	active_count	survival_prob	survival_pct	conditional_retention
0	21439	1.000000	100.000000	NaN
1	10910	0.508886	50.888568	0.508886
2	1311	0.061150	6.115024	0.120165
3	202	0.009422	0.942208	0.154081
4	75	0.003498	0.349830	0.371287
5	43	0.002006	0.200569	0.573333
6	28	0.001306	0.130603	0.651163
7	18	0.000840	0.083959	0.642857
8	11	0.000513	0.051308	0.611111
9	6	0.000280	0.027986	0.545455
10	8	0.000373	0.037315	1.333333
11	8	0.000373	0.037315	1.000000
12	0	0.000000	0.000000	0.000000