



Harvesting Effects of Heat Waves and Pandemics

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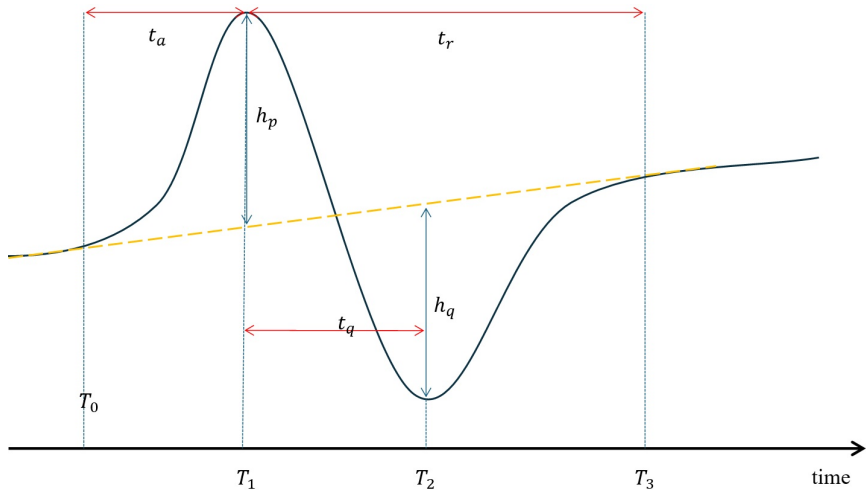


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Mortality displacement takes place when a sudden shock eliminates imminently a **higher than anticipated** number of individuals, especially those that are expected to die soon.

The outcome, in terms of death counts or death rates, is a curve with a **sharp peak**, corresponding to the excess deaths caused by the shock, **followed by a trough**, reflecting the lack of deaths as the expected individuals at risk have already been eliminated.

CPop Harvesting: a simple visualization



CPop Heat Waves vs Epi-/Pandemics

	Heat Waves	Epi-/Pandemics
Harvesting	Strong, short-term	Weaker, longer-term
Mechanism	Triggering	Infection
Spread	Local	Contagious
Healthcare impact	Short surge	Prolonged strain

Harvesting: short-term mortality displacement is often **stronger** and **more immediate** for temperature extremes than for infectious diseases

Mechanism: climate-related shocks often trigger deaths among **already frail** individuals (cardio-respiratory stress), while diseases **create new risk via infection**. Pandemics may also **generate acquired immunity** or **behavioral adaptation** among survivors, potentially modifying subsequent risk patterns

Study two types of mortality shocks: heat waves and pandemics

Check for evidence of harvesting: immediate and delayed

Does “time elapsed since the peak of excess deaths” matter?

CPop Expected deaths

- ▶ Weekly death counts $D_t \sim \text{Poisson}(\lambda_t, \varphi)$ with $\lambda_t = \exp(\xi_t)$ and φ – overdispersion parameter..
- ▶ Serfling method with smooth trend & fixed seasonality (SP-STFS)

$$\xi_t = \nu_t + \beta_1 \sin \frac{2\pi}{52} t + \beta_2 \cos \frac{2\pi}{52} t + \delta_{t,k[t]} + \ln E_t$$

$\nu_t = \sum_i \alpha_i B_i(t)$ with a basis of B-splines $\mathbf{B} = [b_{ti}] = [B_i(t)]$,
 $t = 1, \dots, T$ and $i = 1, \dots, l$
(introduced by Léger, Rizzi & Basellini 2025)

$\delta_{t,k[t]}$ accounts for number and type of holidays in a week
(introduced by Schöley 2021)

CPop Expected deaths: Accuracy

Schöley (2021), using weekly data, and Léger, Rizzi & Basellini (2025), using monthly data, compared the accuracy of forecasts on multiple countries. They arrived at a similar conclusion in favor of a Serfling model with relaxed specification (assuming smoothness as in SP-STFS or something else).

Both studies find, in general, little evidence in favor of harvesting, no matter how expected deaths are obtained.

CPop Extension: Delayed Effects

Idea: Add another term to the linear predictor accounting for delayed effects.

Account for time elapsed from reaching peak in excess deaths, T :

$D_t \sim \text{Poisson}(\lambda_t, \varphi)$ with $\lambda_t = \exp(\xi_t)$ and

$$\begin{aligned}\xi_t = \nu_t &+ \beta_1 \sin \frac{2\pi}{52} t + \beta_2 \cos \frac{2\pi}{52} t + \delta_{t,k[t]} \\ &+ \eta h(\tau_t) \cdot \mathbb{1}_{t \geq T} + \ln E_t,\end{aligned}$$

where $\tau_t = \max(0, t - T)$ and the smooth function

$h(\tau_t) = \sum_j \gamma_j B_j^\perp(\tau_t)$, $\sum h(\tau_t) = 1$ describes the profile over time,

while η scales its overall magnitude (if $\eta < 0$, this is a sign of harvesting).

CPop A Note on Orthogonalized Splines

Post-peak splines can leak variation from trend/seasonality, so the harvesting effect is not cleanly identified. Orthogonalization fixes this: we will construct harvesting shape $h(\tau_t)$ such that it depends only on time since peak and it is orthogonal to the trend and seasonality space.

- ▶ Start with a raw B-spline basis: $B(\tau) = [B_1(\tau), \dots, B_J(\tau)]$.
- ▶ Remove components explained by baseline covariates
 $\mathbf{X} = [\text{trend basis, Fourier terms}]$
- ▶ Compute $\mathbf{B}^\perp = (\mathbf{I} - \mathbf{P}_\mathbf{X})\mathbf{B}$, where $\mathbf{P}_\mathbf{X} = \mathbf{X}(\mathbf{X}^\top\mathbf{X})^{-1}\mathbf{X}^\top$ is the projection onto the baseline space

Heat Waves after 2000 and COVID 19

- ▶ Selected heat waves: 2003, 2015, 2018, 2019, 2022
- ▶ COVID-19 Pandemic
- ▶ Data availability: weekly death counts and exposures
MoCy (github.com/jschoeley/mocy)

Earlier Heat Waves and Pandemics (focus: UK):

- ▶ 1911 Heat Wave in the UK
- ▶ 1889-1890 Russian flu pandemic
- ▶ 1918-1919 Spanish flu pandemic
- ▶ Data availability: weekly death counts
provided by H. Jaadla and R. Davenport (U Cambridge)

CPop Checking for Harvesting

1. Fit SP-STFS baseline (pre-shock)
 - ▶ get expected deaths
 - ▶ compute excess: $\hat{X}_t = D_t - \hat{D}_t$
2. Define peak: $T = \arg \max_t \hat{X}_t$
3. Fit harvesting-augmented SP-STFS model using T
4. Evaluate forecast's accuracy (RMSE, MAPE)

	1911	2003	2015	2018	2022	1918	2020
M	Y	25/28	32/38	31/38	31/38	N	5/38
F	Y	23/28	34/38	33/38	38/38	N	3/38

Table: Proportion of populations with estimated $\eta < 0$.

Comparison of SP-STFS v harvesting-augmented SP-STFS 1-year forecasts in terms of RMSE and MAPE:

- ▶ For pandemics: SP-STFS slightly prevails
- ▶ For heat waves: harvesting-augmented SP-STFS has higher accuracy

- ▶ Suggested model capturing delayed effects, incorporates parameter accounting for harvesting
- ▶ Strong evidence for harvesting due to heat waves (expected)
- ▶ Almost no evidence for harvesting due to pandemics (delayed effects do not playing a major role)

- ▶ Using individual data, estimate shares of people in different states (Robust, Frail, Dead)
- ▶ Study what causes of death have been affected by COVID-19
- ▶ Study impact of COVID-19 on other subgroups (e.g., by residence)

THANK YOU

CPop SDU The logo for SDU, consisting of the letters 'SDU' in a bold, sans-serif font, followed by a stylized black cherry with two leaves on a stem.

The logo for SCOR, featuring the letters 'SCOR' in a bold, blue, sans-serif font. The 'S' and 'O' are connected, and the 'R' has a distinctive shape.

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